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WASHINGTON GEOLOGICAL SURVEY

HENRY LANDES, State Geologist

BULLETIN No. 5

PART I

Geology and Ore Deposits of the Myers Creek Mining District

PART II

Geology and Ore Deposits of the Oroville-Nighthawk Mining District

By JOSEPH B. UMPLEBY

1889

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LETTER OF TRANSMITTAL.

Governor M. E. Hay, Chairman, and Members of the Board of Geological Survey:

Gentlemen—I have the honor to submit herewith a report by Joseph B. Umpleby, with the recommendation that it be printed as Bulletin No. 5 of the survey reports. It is in two parts, viz., Part I, Geology and Ore Deposits of the Myers Creek Mining District, and Part II, Geology and Ore Deposits of the Oroville-Nighthawk Mining District.

Very respectfully,
Henry Landes,
State Geologist.

University Station, Seattle, July 1, 1911.

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PART I.

GEOLOGY AND ORE DEPOSITS OF THE MYERS CREEK MINING DISTRICT.

GEOLOGY AND ORE DEPOSITS OF THE MYERS CREEK MINING DISTRICT.

INTRODUCTION.

LOCATION.

The Myers Creek mining district is situated in eastern Washington, in the northeast corner of Okanogan county, and has for its northern border the international line. Definite boundaries for the area are not on record, but the accompanying map (Plate I) which represents about thirty-six square miles and centers about the town of Chesaw, includes most of that part of the district which has afforded reasonable encouragement to the prospector. Chesaw, the principal town, is a little village of about 500 population and is accessible by stage from Myncaster, a small settlement on the Oroville branch of the Great Northern railway, five miles distant.

FIELD-WORK AND ACKNOWLEDGMENTS.

Field-work was begun August 25, 1909, and continued until September 3, 1909. Throughout the investigation Mr. Olaf Stromme rendered valuable assistance, especially in the areal mapping. For courtesies in the field the writer is indebted to the citizens and mining men of the district, especially to Honorable M. A. Smalley; to James P. Blaine, local assayer; and to Mr. Aaron Anderson.

PREVIOUS WORK.

In 1904 the United States Geological Survey published a topographic map of the Osoyoos quadrangle, which includes the west part of Myers Creek district. In the same year the topographic map of Republic quadrangle was published, this including the eastern portion of the area. Both are on the scale of 1-125,000 and with 100-foot contour interval.

Save for occasional mention in technical journals and a brief statement in an early publication of the Washington Geological Survey (*a*), there is no literature on the district.

References to work in adjoining areas are made in the text.

GENERAL CONDITIONS.

A fairly uniform growth of medium-sized evergreen trees covers most of the western part of the district. Although it is a region of but moderate rainfall (about 18 inches), most of the streams live throughout the year, supplying an abundance of water for mining and other purposes.

Glacial drift is widely distributed, and is especially conspicuous west of Myers creek, where due to its persistence but few rock exposures appear. The general concealment of bedrock makes detailed work in the district very difficult, and since so short a time was spent in field-work it is probably unnecessary to suggest that the accompanying map covers only incompletely those features which are of general interest to the mining community.

(*a*) Wash. Geol. Survey, Annual Report, Vol. 1, Pt. II, pp. 26-28, 1902, Henry Landes.

CHAPTER I.

PHYSIOGRAPHY.

TOPOGRAPHY.

The Myers Creek Mining District is situated in the northeastern part of Okanogan county, in eastern Washington. That part of the district included on the map comprises an area of five miles north and south by about seven miles east and west, the northern line of the area mapped being one mile south of the international boundary.

As will be seen by an inspection of Plate I, elevations range from about 2,650 feet in the valley flat north of Bolster, up to 5,580 feet at the summit of Buckhorn mountain. The valley of Myers creek, which is the central drainage line of the area, divides the district into two parts with dissimilar topography. The eastern division is much higher, more precipitous and rugged, with some deep ravines and gorges; while the country to the west of Myers creek is more gently rolling, and characterized by open valleys. The maximum elevation of the west side is 4,041 feet, in contrast to 5,584 feet on the east side.

In the eastern division of the area the steep slopes are interrupted at frequent intervals by jutting ledges of metamorphosed limestone, which form low cliffs and scarps. Ravines cut in the various formations present little or no difference in topographic expression, and even the area of hornblende syenite to the northeast does not bear any particular relation to topography.

In places west of Myers creek metamorphic rocks protrude through the glacial material either as low ridges or as ledges. The few isolated areas of limestone form little ridges flanked by metamorphic rocks or drift, while the granite represented in the north central portion of the map has no special topographic expression.

The area is drained by short streams of high gradient, nearly all tributary to Myers creek, the largest stream in the district. Myers creek, itself a small stream, flows north into British Columbia through an open valley with a flat which varies from one-fourth to one-half mile in width and with an average fall of a little less than one foot to the hundred. The largest tributary valley is that of Mary Ann creek, which joins Myers creek valley at Chesaw and drains most of the west half of the district. Ethel creek, flowing in a narrow valley, with steep sides much of the distance and rocky gorges part of the way, joins Myers creek from the east a mile south of Chesaw. Lost creek, which drains some of the rugged country in the northeast part of the district, occupies a narrow steep-sided valley and joins Myers creek at Bolster.

SOILS AND CULTURE.

The uplands of the western portion of the district possess deep, rich black soils, derived from the weathering of glacial material. They are of varying texture, though seldom very coarse, and support a fine growth of wild grasses. Timber occurs in scattered groves but is nowhere an important asset, standing thereby in striking contrast to the eastern part of the area which, with a very similar soil and similarly derived, supports a fine forest growth, especially on the north and east slopes.

The soils of Myers creek valley and the valley of Mary Ann creek are very fertile and well adapted to agriculture, but along the other valleys there is only a small area level enough for cultivation.

The principal occupations pursued in the district are farming, mining and stock raising. Wheat yields heavily and is grown in all the larger valleys, and on the uplands of much of the western portion of the area. Vegetables and small fruit are also grown successfully. Owing to the elevation and latitude, the season is short, the nights cold and only the hardier crops of the north temperate zone will mature. Mining is carried on intermittently. The higher reaches of ground and those areas below, in which the topography is not favorable for cultivation, are largely utilized for grazing.

The district is well dissected by wagon roads, but no railroad enters the area. Myncaster, a small station on a branch of the Great Northern railway, is situated about one-fourth mile north of the international boundry, and is reached by stage from Chesaw, a distance of five miles.

GLACIAL FEATURES.

Prior to the advance of the Cordilleran ice sheet the surface possessed that maximum slope known to physiographers as maturity. The uplands were cut by deep "V-shaped" valleys, separated by narrow ridges. The topography then, as now, was more rugged in the eastern than the western portion of the area. With the deposition of drift in the Pleistocene, erosion of the rock surface was temporarily arrested and much of the area assumed the rough topography, which when accompanied by poor drainage, is characterized as youth. Both ground and terminal moraines occur, but are thicker west of Myers creek than east of it. This, however, is likely to be accounted for by the steeper slopes and higher altitudes prevailing in the eastern part of the area, affording greater erosion activity and hence a more extensive removal of the drift. South of Mary Ann creek there is a well-marked terminal moraine, probably formed during the period of general ice retreat. It is particularly striking as seen in section 25, township 40 north, range 29 east, which it largely covers. The moraine is very rough with a most intricate variation from ridges and hillocks to kettles and troughs, differences in elevation being from forty to seventy-five and rarely more than one hundred feet. South of this moraine is a broad expanse of unstratified drift indicating that it was formed during a time of rest in the general period of ice recession.

CORRELATION OF EROSION PERIODS.

The general topography of the country, although not a striking feature within the small area mapped, is that of a broad plateau so intricately dissected by erosion that the remnants of the original surface may be seen only in a few places, its original presence being indicated by the general accordance in summit levels.

Interpreted largely in the light of observations in adjoining areas and the general continuity of the topography to the east into the adjoining Republic district where fossil evidence (*a*) was obtained which dated the old erosion surface as very probably Eocene, it is concluded that the principal topographic features of the Myers creek district are carved from an Eocene surface and hence are post-Eocene in age.

The region is generally known as the Okanogan highlands and is probably to be considered a southward extension of the interior plateau of British Columbia which Dawson (*b*) describes as an erosion surface of Eocene age. (*c*)

(*a*) Wash. Geol. Survey, Bull. I, pp. 12 and 24, 1910.

(*b*) Trans. Royal Society of Canada, pp. 11-13, 1890, G. M. Dawson.

(*c*) These relations are considered in greater detail in a paper by the writer. Wash. Geol. Survey, Bul. No. 1, pp. 11-14, 1910.

CHAPTER II.

GENERAL GEOLOGY.

GENERAL STATEMENT.

The broader features of the geologic history of Myers creek district include sedimentation and igneous activity in the Paleozoic, with great diastrophic movement possibly at its close; batholithic intrusion with accompanying contact metamorphism and mineralization in the late Mesozoic; and erosion and glaciation in the Cenozoic.

The oldest rocks in the area are probably of Paleozoic age and consist of quartzites, slates, schists and limestones with intimately associated intrusive and extrusive igneous rocks of basic composition, all of which have been subjected to a great period of diastrophic movement which resulted in their regional metamorphism. At least part of the series is thought to be Carboniferous. Intruded into these are two great batholiths of acid granular rock which show no evidence of having passed through a period of intense crustal movement and are for that reason, together with other considerations taken up later, assigned provisionally to the late Mesozoic. Erosion was the dominant feature of the Tertiary with possibly a period of movement resulting in elevation, at about the close of the Eocene. In the Pleistocene a southward extension of the Cordilleran ice sheet covered the entire area leaving a heavy mantle of drift, much of which remains in situ, especially west of Myers creek.

DESCRIPTION OF ROCK FORMATIONS.

PALEOZOIC SERIES.

Distribution.

Distributed widely in the Myers creek district is a series of metamorphic rocks; quartzites, slates, greenstones, limestones and schists, named in descending order of importance. They form the bedrock over all the area except that occupied by the quartz-bearing hornblende syenite on the north slope of Buckhorn mountain, and the granite mass northwest of Chesaw. Owing to their general striking appearance and topographic position the limestone beds are represented on the map by special color, while the other members are grouped, and represented by a uniform shade. To differentiate the slates, schists and greenstones would require far more detailed work than the present studies permitted.

Characteristics.

The series as a whole is distinctly, though not intensely, metamorphosed. Foliated schists are seldom seen; the limestone although greatly crushed is seldom converted into marble; and the quartzites seldom present complete recrystallization. On the other hand exposures which show distinct bedding are rare, while in many places secondary structure is the pronounced feature. In point of structure the area may be separated into two parts with Myers creek valley as the dividing line. West of the valley the beds dip, with few exceptions, to the west, while on the east side the dip is in the opposite direction. A section across the western portion from the Molson mine to Chesaw, a distance of about three and one-half miles, presents a persistent dip to the west varying from twenty to seventy degrees but averaging thirty or thirty-five degrees. In the western half-mile of the distance the rock is a pearly, carbonaceous clay slate which is uniformly metamorphosed. It overlies a great thickness of greenstone and micaceous schist which continue to be the predominant rocks for about two miles further east, where the schists give way to quartzites, which with greenstone, prevail to the bluffs near Chesaw. This area is so concealed by drift, and exposures are so scattered, that it is not thought safe to make an estimate of thickness on the strength of the above observation, although the traverse was undertaken with that end in view. Suffice it to say, that the section represents a very considerable thickness of beds with the general transition of the sedimentary part, from quartzites below through schists to clay slates above.

East of Myers creek valley the clastic and igneous parts of the series seem to be very similar to those on the west except that there is much more quartzite and less greenstone, while limestone is vastly more abundant. The prevailing strike is a little east of north with dips to the east at angles varying from ten to sixty degrees but averaging about thirty degrees. The best section of the formations that was found, is in the west half of section 34, township 40 north, range 30 east, where several small outcrops of metamorphic rocks are exposed as occasional low ledges for several hundred feet up the slope. The beds strike in a direction varying from north to a little west of north, and dip easterly at angles ranging from thirty-five to sixty degrees. A pace-traverse across the strike from west to east presented for the first six hundred feet, an alternation, beginning and ending with schists, of six beds of coarsely crumpled micaceous schist with five beds of gray to greenish quartzite of medium texture, the several beds of each being of about the same thickness. The most easterly of the schist members encloses a tabular body of basic porphyry which seems to conform with it in dip and strike. Above this schist is quartzite which grades from brown at the bottom through red and pink to white at the top. It is about 100 feet thick and is overlaid by an equal thickness of mica schist which gives way to a thin bed of marble. Greenstone next outcrops for twenty feet or so with about fifty feet of marble beyond. Then follows one hundred feet of schist with a thin body of greenstone included. Greenstone is next above and forms the most easterly exposure.

A feature that is characteristic of the entire area is well illustrated in the above exposures where many beds which are strong and well defined can not be traced for more than a few hundred feet along the strike. In the case of limestone they seem to pinch out, while with the clastic rocks the breaks are probably due in large measure to cross faulting, and sharp bends along the strike which have resulted in increasing or decreasing the resistance of the bed to weathering.

The limestone beds are fairly free from impurities but in places tend to be siliceous with occasional bands of scattered chert nodules. The average rock is dark gray to dove color on exposed surface, but on fresh fracture is either uniformly bluish gray or shows alternating blue and white bands. In a few places the more solid color is mottled by blue spots. Usually the limestone is greatly crushed although not recrystallized, but in places beautiful marble occurs in parts of a bed. It is thought that such local instances of marbleization can in each case be traced to the contact influence of a nearby igneous rock.

The lenses of limestone are usually small in horizontal extent and less than a hundred feet thick. One bed outcrops on the west face of Buckhorn mountain which is much larger than the others and because of its peculiar outlines justifies special mention. It begins in the bluffs east of Chesaw at an elevation of 3,600 feet and continues up the mountainside to a height of 5,000 feet, throughout the entire distance dipping east at an average angle of about 30 degrees. Since the horizontal distance between the western or lower exposure and the eastern or higher, is a little more than one mile, it will readily be seen either by computation or plotting (Fig. 1) that this bed, if its lower part continues on its dip under the mountain, is approximately 4,000 feet thick. The bedding planes within

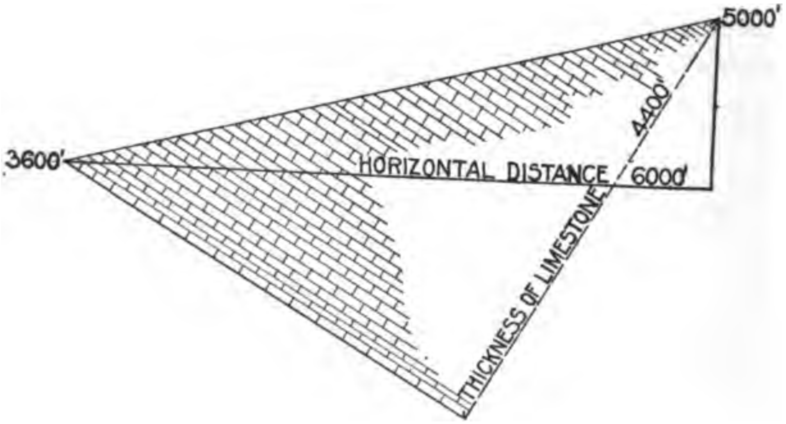

FIG. 1.—Method used in determining thickness of limestone occurring on the west face of Buckhorn Mountain.

the mass are usually distinct and since the dip recorded above is a conservative average of several dips taken at different points, there seems little room to doubt that the above estimate of thickness follows from field relations. Attempt to harmonize this thickness, however, with the distribution to the north and south and it is obvious at once that special relations exist. An inspection of the map shows that to the south along the strike the lower part of the deposit pinches out within one and one-fourth miles from the longest east-west axis of the outcrop; half-way up the mountain a southward tongue extends for about a half-mile; and at the top a narrow tongue extends in the same direction about three-fourths of a mile. On the north margin the boundary is more regular but even here two protuberances extend for about one-half mile each. It does not appear that faulting will explain these irregularities in outline. The relations then are, that the bed of limestone is about 4,000 feet thick with a horizontal extent in its lower portion along the axis which corresponds to the present strike, of only about 8,000 feet. On horizons successively higher stratigraphically, the horizontal extent of the mass presents striking and irregular variations.

It would seem that the deposit must have taken its present form either by the crushing together of a more widely distributed limestone bed during the period of crustal movements, or by peculiar conditions of deposition whereby a reef of lime-bearing organisms continued to exist for a long time while clastic sedimentation was going on around it. The degree of preservation of the bedding structure seems to favor the latter view.

The igneous rocks intimately associated with the sedimentary series are basic in composition and so completely altered that the original mineralogical composition was not determined satisfactorily. They fall either in the gabbro or the diorite family, although in their present forms they may well be designated by the term greenstones. In many of the specimens the secondary minerals have been developed in part from a glassy ground mass, remnants of which remain. In others distinct outlines of original crystals remain in most parts of the section. It seems, therefore, that the original rock varied in texture from glassy or slightly porphyritic to holocrystalline, thus implying the presence of both extrusive and intrusive types. That some of the rocks are intrusive is in keeping with the above section where the limestone both above and below the body of basic igneous rock is changed to marble. Although it is thought that the extrusive phase is far more extensive than the intrusive, their relative importance is not definitely known.

Age.

The only fossils found in the series were from the limestone outcrops in the northwest quarter of section 26, township 40 north, range 30 east. These consist entirely of crinoid stems which, although quite abundant, are fragmentary. They were of little value in age determination although in harmony with a correlation with known areas in Canada. Lithologically and structurally the series is very similar to the Cache creek series of Dawson, which is of known Carboniferous age, (*a*) and largely on the strength of this analogy the series is provisionlly assigned to the Carboniferous although there seems little doubt that beds of more than one age are present.

In this connection one feature was noted which may have special bearing when the conditions of sedimentation are studied in greater detail. In the southeast quarter of section 10, township 40 north, range 30 east, is a prospect tunnel about 150 feet deep which is driven in a metamorphosed conglomerate. The individual boulders vary in size up to about ten inches in diameter and consist of slate, schist and quartzite, with perhaps some meta-igneous material, in the ratio of about 1 : 1 : 7. This conglomerate was not seen elsewhere in the area, although the general concealment of bedrock by glacial drift and residual soil makes this statement of little significance.

(*a*) Annual Report, Geol. Survey, Canada, New Series, Vol. 7, 1894, pp. 37-B to 49-B.

MESOZOIC ROCKS.

Distribution.

The Mesozoic history of the district seems to be that of erosion and intrusive igneous activity. There are two great batholithic masses of slightly different composition within the area. The larger is a quartz-bearing hornblende syenite and outcrops over an irregular extent of about four square miles in the northeast part of the area. The other mass is granite and occupies about two square miles northwest of Chesaw.

Characteristics of Syenite.

The average specimen from the quartz-bearing hornblende syenite mass is a dark bluish gray rock of inequigranular to equigranular texture and megascopically consisting of hornblende and feldspar with local development of biotite and an occasional grain of quartz. The texture varies considerably, in places being uniformly about equigranular while in others hornblende crystals are far larger than the feldspars and yet again feldspars of two distinct sizes appear. Quartz and hornblende both have a considerable range of variation, the former running from one-half of one per cent. to about seven per cent. of an entire thin section although in one instance twenty-five per cent. of quartz was noted, while the hornblende varies between eight or ten per cent. and twenty per cent. In thin sections the feldspar is shown to be about one-fifth albite and four-fifths orthoclase with occasional microcline crystals.

The syenite is in the form of a batholith very irregular in outline as exposed at the surface and having an areal distribution of about four square miles. The mass has been thrust up into the sediments without having very appreciably influenced their dip. It is probable that in general outlines the batholith is much more regular than the surface outcrop indicates, *i. e.*, that many of the sedimentary tongues which extend into its general area simply represent portions of the cover not yet removed by erosion.

Along the margins of the igneous mass intense metamorphic action has taken place locally. The localization of the alteration seems to depend in large part on the character of the adjacent material, for at the point of most pronounced metamorphism an entire bed of limestone has been changed while quartzites adjacent to the limestones and even closer to the syenite, have suffered no appreciable metamorphism. It is also noteworthy that the only altered area is at the same time the only limestone bed in contact with the syenite. Where schists or slates come in contact, occasional garnet and epidote crystals have been formed but within the limestone they are about equal in amount to the calcite, which is probably residual from the original rock. Diopside, actinolite, tremolite and titanite are developed in amounts which vary from place to place. The texture of the altered rock is never coarse and it is frequently impossible to ditinguish the outlines of individual crystals with the unaided eye. In thin sections the garnets are seen to be scattered heterogeneously through the slide both as isolated crystals of four, six, or eight sides, and as groups of irregular outlines. The epidote (green) occurs as prisms and grains, frequently with interrupted boundaries. Calcite forms the matrix for the metamorphic crystals. Actinolite occurs as long prismatic crystals clustered in more or less radiating groups, while tremolite has a similar distribution but is much less abundant. Diopside is locally very conspicuous although it does not appear in many of the slides. Titanite, which is found as small automorphic crystals and as rims surrounding magnetite, is quite uniformly distributed but there are never more than one or two occurrences in any one specimen. The metallic minerals developed in the area are magnetite (which forms the principal surface rock over an extent of several acres), chalcopyrite the chief ore mineral, and pyrite, a common associate of both of the others.

Within the igneous rock itself the hornblende is commonly altered to epidote and chlorite, and the feldspars to epidote, zoisite and sericite. In both hornblende and feldspar green epidote is the chief alteration product. Pyrite is usually developed as cubes irregularly distributed. Magnetite is present but not conspicuous. Since the minerals developed in the contact rock and within the mass itself are so similar and do not have the balance usually found in the common weathering of an igneous rock, it appears that both were subject in part to the same metamorphosing agencies, indicating thereby that part of the metamorphosing action took place after the solidification of the outer shell of the batholith. This phase of the alteration is known as hydrothermal metamorphism and probably resulted from escaping vapors and gases which emanated through both the outer part of the igneous mass and through its sedimentary cover, during the period of solidification of the inner part.

Characteristics of Granite.

The average specimen from the granite area differs from that of the syenite mass only in a greater amount of quartz and a lesser amount of hornblende. It is possible to secure specimens in this area which would undoubtedly be classed as syenite, as it is also possible to secure some from the other which would be classed as granite. The typical specimen is a light gray rock varying in texture from granular to inequigranular, and composed of orthoclase with about one-third as much albite, quartz, hornblende and biotite. The last two minerals named are about equally important and together make up from four to ten per cent. of the rock, varying in amount in different places. Chlorite and sericite are the more important secondary minerals, although pyrite has been extensively formed in a few places.

As far as observed the granite did not produce much alteration in the rock which it intrudes. This may be due to the absence of limestone along the contact, since in the syenite area it was the only type that was greatly altered.

The granite has a surface exposure of about two square miles, and like the syenite was intruded into the Paleozoic series as a batholithic mass which apparently had little effect on the general structure of the formations which it entered.

Age of the Batholiths.

These batholithic masses are clearly younger than the Paleozoic series which incloses them, and since they are not schistose, evidently are younger than the period of structural movements which metamorphosed that series. From an analogy to adjoining areas it is suggested that probably this area was peneplained in the Eocene. If this is true it is noteworthy that syenite outcrops up to an elevation of 4,900 feet on the east margin of the area, whereas the peneplain surface varies from 5,000 to 6,000 feet. This will scarcely allow enough cover to produce the granite texture characteristic of the mass unless the intrusion be dated as pre-peneplain. From the foregoing evidence the batholithic masses are provisionally assigned to the late Mesozoic.

CENOZOIC DEPOSITS.

The Cenozoic era seems to have been a time of erosion, continuous save for the comparatively short period when glacial ice covered the area. Glacial drift is found in all parts of the district although it is much more pronounced on the west side of Myers creek valley than on the east. This is probably due rather to a greater amount of post-glacial erosion on the east due to steeper slopes, than to any original difference in amount of the deposits. An irregular terminal moraine extends east and west across the southwest part of the area mapped. South of it a heavy mantle of unstratified drift extends well beyond the limits of the district, indicating that the terminal moraine simply represents a time of rest during the general period of ice retreat. Ground moraine material is far and away the most widespread type of glacial deposits. Along Mary Ann creek are local terraces composed of stratified glacial material which was probably deposited in a small lake formed in front of the ice after it had retreated north over the divide between Myers creek and Antoine creek or possibly between Myers creek and Beaver creek (*a*).

(*a*) See the topographic sheets of U. S. Geol. Survey, Osoyoos and Republic Quadrangles.

CHAPTER III.

ECONOMIC GEOLOGY.

LOCATION AND CONDITIONS.

The Myers Creek mining district is situated in the northeast part of the Osoyoos quadrangle, in eastern Washington. Like most of the mining districts of this part of the boundary country, it is unorganized. The accompanying map, which includes about thirty-five square miles, covers most of the area and indeed all of that part which has afforded reasonable encouragement to the prospector.

Elevations within the area vary from about 2,650 feet in the valley flat north of Bolster, up to 5,584 feet at the highest point on Buckhorn mountain. Myers creek, which is a small stream crossing the area near its center and flowing north into Canada, is the principal drainage line, and from it the mining district receives its name. The stream occupies an open valley with a flat from ten to fifteen rods wide and has an average gradient of a little less than one hundred feet per mile. Ethel creek, a small westerly flowing stream with a gradient of between six and seven hundred feet to the mile, occupies a comparatively narrow valley and joins the main stream about one mile north of the south boundary of the area mapped. Three-quarters of a mile farther north Mary Ann creek enters the main stream through an open valley from the west. At Bolster, Lost creek, draining a precipitous country to the east, joins Myers creek.

The central drainage line divides the area into two topographic types; that to the east being precipitous and largely covered with a dense forest growth, especially on the north and east slopes, while to the west the topography is made up of high, rolling hills reaching a maximum elevation 1,543 feet lower than to the east, and supporting only scattered and in many instances, isolated trees.

The Great Northern railway, giving ready communication with Spokane and various British Columbia points, reaches Myncaster, a small settlement in British Columbia about five miles north of Chesaw. At present wagon roads extend to most parts of the area and all of the remaining parts can be entered by roads at very reasonable cost if mining developments make them necessary.

As a whole the district is well supplied with timber. No water power sites of economic importance occur within the area although there is an abundance of water for milling and domestic purposes. Climatic conditions on the average are more favorable to mining than in most of the camps in the northwest states.

HISTORY AND PRODUCTION.

The district is comparatively young, the principal locations having been made since the reconnaissance by the Washington Geological Survey, recorded in its annual report of 1902. (*a*) The production has not been great, probably falling within $100,000, about $40,000 of which came from the placers on Mary Ann creek, $15,000 from the contact metamorphic deposits on Buckhorn mountain and the remainder from the Butcher Boy and other veins of the area.

Development has been largely by tunnel, although there are a few shafts. There are no deep workings, the Grant tunnel, which at the face is about 400 feet vertically below the surface, probably being the deepest. It must not be inferred from this statement, however, that exploration in depth, beyond the limit of surface alteration, which is always shallow (fifteen to fifty feet) in this area, will reveal values greater than those immediately below the lower limit of oxidation, for although a prevalent view among prospectors, it is not supported by the geologic relations here existing. There may be special exceptions to this on Buckhorn mountain but these will be taken up later under the head of contact metamorphic replacement deposits.

Most of the development has been done without the aid of power-drills. Four small amalgamation mills are situated in the

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(*a*) Washington Geological Survey, Vol. I, part II, page 26.

area but have not proven very satisfactory, due to low extraction and the general pyritic nature of the ore; and since there is usually too much copper for satisfactory cyanidation, it is probable that smelting will prove to be the most feasible treatment.

GEOLOGIC RELATIONS.

The rock formations of the area are a great series of Paleozoic sediments, lava flows and porphyries, which have been intruded, probably in Mesozoic times, by batholiths of igneous rock—quartz-bearing hornblende syenite and granite. Along the contact of these intrusive masses with the sediments there are in a few places areas of intensely metamorphosed material which carry copper, gold, and silver, commercially important in the order named.

The igneous rocks of the district are of two ages, the earlier being basic flows, dikes and sills, of Paleozoic age, and the latter acid granitic rocks, tentatively assigned to the Mesozoic. The basic rocks are widespread in the district and outcrop as ledges and cliffs where the enclosing rock is slate or schist, while their presence is indicated only by float where the enclosing rock is quartzite. In the one exposure where they were found in contact with the limestone, the latter had been changed to marble both above and below the igneous rock, thus indicating in that particular instance an intrusive origin. Microscopically the rock is largely made up of secondary hornblende, although epidote, zoisite, sericite, magnetite and pyrite have been developed in decreasing importance in the order named. Outlines of olivine and augite, together with chance unaltered or partially altered fragments, appear in the slides. The feldspars are nearly always completely altered but from rare fragments remaining in a determinable form, it appears that andesine was possibly the prevailing type. Quartz is present but is largely secondary. The above balance of mineralogical composition, in so far as it is comprehensive, places the rock on the border line between andesite and basalt; although it is not certain that the primary texture, at least locally, was not coarser than these types imply.

Greenstone is probably the most appropriate name for the rock in its present form.

Of the two acid granular rocks, the quartz-bearing hornblende syenite occupies a larger area than the granite. It is bluish gray, with equigranular texture, and outcrops in the eastern part of the area over an irregular extent of about four square miles. Structurally, it is a great batholith intruded into the sediments without having noticeably influenced their dips. The mass is probably much more regular in outline than the contact shown on the map would indicate, it being thought that in large part the tongues of older rock which extend into its general field are comparatively thin portions of the original cover not yet removed by erosion. It is noteworthy that near the southern limit of the area mapped two small areas of syenite are exposed which are possibly spurs from the same underlying batholith, the northern exposure of which has just been described.

Adjacent to this igneous unit extensive contact metamorphism has occurred wherever the adjoining rock is limestone and much less where it is schist or slate, while the effect has not been important when greenstone, and even less when quartzite, is the rock in contact. The age of the quartz-bearing hornblende syenite is discussed in the chapter on General Geology, and is there provisionally assigned to the late Mesozoic.

A batholith of light gray granite outcrops over an irregular area of about two square miles in the north central part of the district. As is true of the syenite above discussed this batholith seems to have had little influence on the general structure of the sedimentary beds which it intruded. Microscopically examined, the rock is equigranular, consisting of orthoclase, quartz, albite, hornblende and biotite as principal constituents, with accessory pyrite, magnetite, titanite and apatite. Sericite, chlorite, zoisite and titanite are secondary. Contact metamorphic action is not conspicuous with the hand lens and was only noted in one or two places where thin beds of limestone were cut by the intrusive body. The ore deposits in the vicinity are usually in the Paleozoic series, but near the granite.

The sedimentary rocks of the area are of varying character, and have been metamorphosed to slates, schists and quartzites, with intermediate phases. Quartzite is the most common type, and varies in texture from large angular to subangular grains, firmly cemented and in places recrystallized by additions to the original grains, to small irregular to rounded grains also firmly cemented; and in color from bluish white through gray and various shades of brown to slate black. Gray quartzites of medium texture are most common. The slates of the series are usually black and very siliceous while the schists present all gradations from incipient schistosity to intricate foliation. Schists are not a conspicuous element in the series. The limestones of the district are very largely confined to the southeastern part where they occur over areas of peculiar shapes, probably signifying both special conditions of formation and a certain crushing together at the time when dynamic movements and stresses caused the general regional metamorphism. Their present form is that of great lenses, very irregular in thickness and extent.

It is very probable that more detailed study would make possible the division of this series into parts, but the present work merely suggests that the great group of massive gray quartzites and basic porphyries which exclusively occupy the northwestern part of the area are younger than the limestones and accompanying slates and schists in the southeast portion.

The series is of doubtful age, although that part represented by limestone bears crinoid stems which are in perfect harmony with an assignment to the Carboniferous, which is also suggested by analogy to known areas in British Columbia. (*a*)

Both the primary and secondary structure of the region is complex. In the western part of the area the prevailing dip is in a westerly direction while in the eastern part it is easterly. Myers creek valley represents approximately the dividing line between the easterly and westerly dipping beds. In a few places an unconformity in dip between the limestones and under-

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(*a*) Annual Report, Geological Survey, Canada, New Series, Vol. 7, 1894, pp. 87 Btd.-89-B.

lying beds is suggested, but by no means demonstrated, due to inability to find exposures in sufficiently close proximity.

The entire series of sedimentary rocks and the accompanying basic porphyries are metamorphosed to a greater or less degree. Superimposed on this general regional metamorphism is intense local contact and hydrothermal metamorphism due to the granite and syenite bodies, while the latter masses do not present evidences of diastrophic disturbances. The regional metamorphism took place, therefore, after both sedimentation and the period represented by basic igneous activity, but prior to the acidic intrusions. As discussed elsewhere, it is thought probable that the dynamic forces which caused the regional metamorphism are to be assigned to that great period of general diastrophic activity which closed the Paleozoic era.

ORE DEPOSITS.

Within the Myers Creek mining district two great classes of ore deposits are represented; namely: (a) contact metamorphic replacement deposits, and (b) fissure veins. The region may be considered a copper-gold district, the copper being largely in the contact zones and subordinately in veins, while the gold is principally in veins and subordinately in the contact deposits. As is usually true in similar camps, it is in some instances impossible to draw the line between the two types of deposits. In places the solutions have acted directly on the adjacent rock, thus producing the irregularities typical of contact metamorphism. In others they have encountered directions of easy passage and deposited along fracture zones, thus giving the tabular form typical of vein deposits. All gradations exist between the two types and indeed there are instances in the area where both extremes occur in the same deposit. In the following discussion only the two types are recognized and gradational phases are included in the class nearest to which they approach.

CONTACT METAMORPHIC REPLACEMENT DEPOSITS.

Location and Characteristics.

The contact metamorphic replacement deposits occur chiefly in the eastern part of the area along the west side of the south extension of the quartz-bearing hornblende syenite. The outcrops which prevail here are seldom oxidized for more than a few feet below the surface and in many places unaltered pyrite, magnetite and chalcopyrite can be found at the grass roots. It follows of course that with little oxidation there has been little leaching, and hence little or no secondary enrichment may be expected as development proceeds.

The ore bodies are of irregular shape, varying in size from small isolated bunches to masses which afford large stopes. Development has not proceeded far enough to make a tabulation of the eccentricities of the deposits feasible, but it is probable that they will be found to have a north-south trend, and easterly dip since both the limestone bedding and the jointing of the area incline in that direction, although the jointing is nearly vertical while the bedding seldom has a dip higher than 40 degrees and usually less than 20 degrees.

The contact metamorphism here described has resulted from the intrusion of the quartz-bearing hornblende syenite into the Paleozoic series. An inspection of the map (Plate I), where the principal area of alteration is indicated as a separate unit, portrays the peculiar localization of the metamorphic action. This is to be accounted for largely by the presence originally of a bed of limestone at this point which was essentially co-extensive with the altered area, while elsewhere along the contact the adjacent rock was of clastic origin with occasional greenstones interbedded. It is noteworthy that the syenite lying east of the mineralized area is a narrow band extending along the east face of the mountain and in places widening in the valleys and narrowing on the divides; whereas on the north it swings west and is the rock in contact along that border of the metamorphic body. This general relation suggests that the mineralized and altered limestone is, in part at least, a capping over a portion of the syenite batholith. The intensive alteration here, in contrast to the inconspicuous change elsewhere, is likely due to the absence of limestone in juxtaposition at other points and is in keeping with the observation made in many localities that limestone is much more susceptible to contact influences than clay slates and quartzites.

It follows from the above that those beds of limestone which lie west of the syenite area and dip toward it offer ground which is worthy of prospecting wherever the contact between the two can be reached without too great expense. It is probable that there are bodies of ore on Buckhorn mountain which have no surface indication and can only be located by determining the probable position of the contact of a limestone bed with the syenite and then prospecting that ground. Such prospecting will be expensive and should not be undertaken until the merits of the mineralized body which is exposed at the surface and is now being worked, are more fully determined.

Minerals.

The mineralogy of the contact ores as here set forth, is undoubtedly far from complete, due both to the limited number of exposures available and to the hurried nature of the examination. Far and away the most conspicuous metamorphic silicates are garnet and epidote. Accompanying them are zoisite, diopside, actinolite and tremolite. Calcite is always present and in greatly varying amounts, while a little titanite appears in most of the slides. More typical specimens from the metamorphic area are of dense, fine-grained rock of yellowish to brownish green color and resinous to vitreous luster, consisting of calcite and small grains of garnet and epidote, with occasional needles of actinolite.

Calcite. In the thin sections calcite is the most important mineral, occurring in the interstices between the other crystals and as irregular patches frequently surrounding isolated groups of garnet and epidote. It represents about thirty per cent. of the average slide.

Garnet. Next in importance is a light green to colorless garnet (grossularite, $Ca_3Al_2(SiO_4)_3$) which, as seen in the sections, has four, six or eight sides. It is distributed both as isolated crystals scattered irregularly through parts of the slide, and as groups in which the individuals are as grains with many variations in outline. Garnet comprises about twenty per cent. of most sections.

Green Epidote. Green epidote (pistacite, $Ca_2(AlOH)$ $(Al\ Fe)_2$ $(SiO_4)_3$) is almost as important in amount as garnet, and has much the same distribution. It occurs as prisms, rods and grains, the latter being readily distinguished from grains of garnet by cleavage, pleochroism and birefringence.

Zoisite. Zoisite $(Ca_2AlOH)Al_2(SiO_4)_3$) is much less important than epidote and occurs as rods and leaves which in most sections are readily distinguished from the epidote by their parallel extinction. When the section of the epidote is at right angles to the cleavage the distinction is more difficult.

Actinolite. This calcium, iron, magnesium silicate $(Ca(MgFe)_3(SiO_3)_4)$ which is very largely limited to the contact metamorphic replacement deposits, constitutes about ten per cent. of some slides. It occurs in thin prismatic crystals clustered in more or less completely radiating groups which are scattered irregularly through the slides.

Diopside. Diopside $(CaMgSi_2O_6)$ is absent from all the slides save one, but in that, it constitutes about seventy-five per cent. of the entire section. The individual crystals occur as grains and short prisms which seldom have their complete crystal outline. The garnets appearing in the same slide are bounded by definite crystal faces except where an individual of the same species is in contact, when one of them usually is complete in form at the expense of the other.

Chalcopyrite. Although less important quantitatively than magnetite, this is the chief ore mineral of the area. In places it occurs as a scattered intergrowth with the other metamorphic minerals, but in most instances is in bunches of considerable extent with pyrite, magnetite, and quartz as the chief accompanying minerals. In the light of present studies no law of probability regarding the position of the chalcopyrite bodies within the altered area, can be stated. The chalcopyrite carries small amounts of gold and silver.

Magnetite. This mineral occurs in great bodies near the central part of the metamorphosed zone, almost to the exclusion of other minerals. Some specimens show pyrite and chalcopyrite intergrown with it. The magnetite usually is accompanied by gold in amounts varying from seventy-five or eighty cents up to seven dollars per ton.

Pyrite. No considerable mass in which pyrite predominates was noted, but probably no mineral is present in so many different exposures. In the veins near the contact metamorphic area pyrite carries gold and it is likely that part of the gold in the contact deposits is associated with it. Its occurrence is in crystalline masses which may be any shape, and less commonly, as cubes and octahedrons.

Titanite. Titanite ($CaSiTiO_5$) occurs in all the slides, but only in rare instances reaches as much as one per cent. of the total content. Rhombs, prisms and grains, all with clearly defined boundaries, are the rule, although in a few instances the titanite surrounds a grain of magnetite as a narrow band, apparently derived from it.

Quartz. This is common in all the altered rock, although seldom reaching as much as five per cent. and usually not more than one or two per cent.

Secondary Alteration.

Within these deposits secondary alteration of the original minerals is a very inconspicuous feature. Copper and iron stains occur at the surface in most exposures but never extend to a depth of more than a few feet. This is in keeping with the general impervious character of the deposits shown by the retention of water, even in shallow shafts, throughout the entire dry season. As a result of these conditions, which evidently have prevailed since the deposits were formed, it follows that zones of secondary concentration cannot be expected in the area.

Genesis.

The genesis of the ores of the garnet-epidote area is well defined by the peculiar association of minerals and geologic relations which in recent years have become commonly known as definite criteria for the identification of contact metamorphic deposits. The minerals which are exclusively of contact metamorphic origin are few and rare, but there is a considerable list which, when found more or less complete to the exclusion of other minerals which accompany them individually under different conditions, are typical of such deposits. The assemblage above noted, namely: of garnet, epidote, zoisite, actinolite, tremolite, diopside and titanite is conclusive proof of such origin. Magnetite, chalcopyrite and pyrite, although not in any measure peculiar to contact deposits, are very common in them. A local relation pointing to the same conclusion is that the particular limestone bed, which of the several mapped, shows intense alteration, is also the only one which lies in contact with a large igneous mass. Further, the irregular outlines of the deposits themselves, impregnation of minerals in the surrounding material, and isolated bunches of ore, all point in the same direction.

The solutions, probably in part emanating as gas and hot liquids from the syenite both at the time of its injection and during the period of cooling when gases and possibly magmatic waters were being eliminated probably by the selective forces of crystallization, and in part ground water made potent by proximity to the igneous mass, penetrated the adjacent rock wherever possible. They removed some of the mineral present and introduced new material in its place, at the same time making it possible for part of the old material to enter into combination with the new, thus forming the minerals before mentioned.

The present conception of most investigators regarding the formation of the contact metamorphic minerals is that in part they are due to the rearrangement of impurities in the limestone remaining after a part has been eliminated by heat, largely as carbon dioxide gas. In larger part, however, they are considered as the result of a combination of added material with residual material on the one hand, and of direct addition on the other. In this particular case the small amount of iron in the other lime areas and the great amount of iron present in the metamorphosed bed, leaves little room for doubt that iron was introduced. Second to iron, copper and sulphur are important additions. The studies were not sufficiently refined to justify a conclusion concerning the introduction or otherwise of the aluminum, magnesium and silicon present in the various silicates. The presence of silica in all the specimens and as a gangue in the nearby vein deposits, suggests that it was introduced, at least in part. Titanium and gold are rarer elements which may or may not have been introduced.

VEIN DEPOSITS.

Distribution and Characteristics.

Veins found in widely separated parts of the district have been opened in all the types of rock present. They are irregular in strike and dip, having, however, a prevailing north and south direction. The dip seems to have no relation to the bedding, although the prevailing strike corresponds in general to that of the structural features of the region. The lodes vary greatly in width in different deposits, and from place to place in the same deposit. They are usually much faulted, and can never be relied upon to carry their width or metal content for a distance of more than a few feet either along the strike or the dip. In some instances commercial ores are limited to well-defined shoots, although for the region as a whole, the irregularities in width and persistence of the deposits themselves are more pronounced than variations in metallization from place to place in the same vein. The walls are usually well defined although spurs and swells into them are common.

The minerals noted are free gold, chalcopyrite, pyrite, galena, sphalerite, arsenopyrite, and occasionally pyrrhotite in a gangue which varies in composition from quartz-calcite to quartz. The quartz is usually coarsely crystalline and of bluish cast while the calcite is white to colorless and, although of irregular outline in the vein, when coarsely crushed reveals its rhombohedral crystallization. Within the vein the metallic minerals have great variations in arrangement, presenting a rough banded structure in places and a succession of irregular aggregates in others, both types frequently being in the same vein. Crustification is rarely seen. Of the several metallic minerals above noted all or a part may occur in any given deposit, pyrite, however, being always present and usually leading in amount.

Oxidation extends only to very moderate depths, primary sulphides predominating below a point fifteen or twenty feet beneath the surface. As would be expected from the above, the level of groundwater is very near the surface throughout most of the area, even shallow prospect pits on the hillsides being partially filled with water during the dry season.

Veins in the western part of the area have given rise to placer deposits along Mary Ann creek which have yielded about $40,000. The placer gold is of medium to coarse size and occurs in gravels, part of which are glacial.

Genesis.

The veins on Buckhorn mountain are in very intimate association with the contact deposits; indeed the gradation between the two can be traced step by step, for in places a vein will make out into the wall from an irregular body of unmistakable contact origin, while in others the reverse relation exists. An instance was noted in the south end of the principal stope of the Grant Mine where the large irregular body narrows within a few feet to a vein about forty inches wide which stands between well-defined walls. This being true and since the contact deposits here found, as already discussed, are genetically related to the quartz-bearing hornblende syenite, there seems little room for doubt that the vein solutions also were dependant on that mass for their activity. Accepting, therefore, the genetic relation of the veins on Buckhorn mountain to the igneous mass there found, it is worthy of note that the deposits north of Chesaw with one exception, are all within one mile of an extensive outcrop of granite. The Molson mine in the northwestern part of the area is about two miles distant. This general distribution of deposits near the granite and their complete similarity in internal characteristics to those found on Buckhorn mountain, which by their gradation into the contact type clearly indicate a genetic relation to the syenite, seems to afford ample justification for considering these deposits as genetically related to the granite batholith.

Pyrrhotite, although never abundant, occurs in several of the veins. It is a sulphide of iron which forms only under very intense conditions of heat and pressure, and thus when found in a vein, may be considered as indicating deposition at great depth, and the deposit in which it occurs should be assigned to the deep vein zone. This mineral, then, occurring near the surface at present, suggests a vast amount of erosion, possibly half a mile or more, since the veins were formed. Extensive erosion since mineralization is also indicated by the surface exposure of granite—if we accept a genetic relation between the two—because its holocrystalline nature implies slow cooling, and slow cooling necessitates a considerable cover at the time of intrusion. The other vein minerals found are not of special significance in determining depth of deposition for they may occur in both the deep and moderately deep zones.

Briefly stated, it is concluded that the veins were formed at great depth and by hot solutions either emanating from or made potent by the nearby igneous masses both at the time of their injection and during the period of crystallization immediately following.

PLACERS.

Placer gold was discovered on Mary Ann creek in 1888 and placers have been worked intermittently and by crude methods ever since. The work has extended along the creek for about one and one-half miles in sections 1 and 2, township 40 north, range 29 east. The ground is now owned by the Allen Mining Company, with a western office at Chesaw. Gold is fairly evenly distributed through the gravel, which varies from two to six or seven feet in thickness. The gold is coarse, no mercury being necessary to save nearly all of it. Many of the boulders in the deposits are distinctly of glacial origin, indicating that the deposits, at least in their present form, are of post-glacial age.

Mining on the creek will probably never be pursued on a large scale because of the very limited supply of water during most of the year. The creek has produced about $40,000.

MINERALS OF DISTRICT.

The list of minerals recorded in a reconnaissance report must obviously be incomplete, but for purposes of reference those noted are arranged in alphabetical order and their modes of occurrence briefly given.

Actinolite. This mineral is widely distributed in the contact area on Buckhorn mountain, but was not found elsewhere. It seldom constitutes more than a small fraction of a specimen and occurs as irregularly scattered groups of more or less completely radiating needle-like crystals.

Azurite. Copper carbonate is limited to the upper few feet of the copper deposits and even here is not conspicuous. It occurs as films lining the fracture planes of copper sulphides, and as stains on nearby rock.

Bornite. This frequently occurs as an alteration product intermixed with chalcopyrite in the upper levels of the copper properties. It is not an important ore.

Calcite. Calcium carbonate is found in many of the vein deposits as a part of the gangue and in the contact deposits as residual from the replaced limestone.

Chalcocite. A single plate-like deposit of copper glance was noted along a small joint in the Grant mine. Chalcocite was not seen elsewhere.

Chalcopyrite. Chalcopyrite is the chief ore of copper. It is largely found in the contact zone, although occurring in the veins in amounts which vary from place to place.

Chlorite. This common secondary mineral is widely distributed in various rocks in the area.

Diopside. Diopside is locally very abundant in the contact zone and was also noted in some of the slides of regionally metamorphosed rock.

Epidote (Green). Green epidote occurs very extensively as a contact mineral on Buckhorn mountain and as an alteration product from feldspar and hornblende in much of the syenite and granite. It was also noted in some of the specimens of regionally metamorphosed rock.

Galena. Many of the veins carry galena, although no lead deposits of commercial extent are known in the area.

Garnet. This mineral, as far as observed, is confined to the contact metamorphic area on Buckhorn mountain. Here it frequently constitutes a quarter or more of the entire mass. No slide from the contact area was studied which did not contain it. The crystals are usually very small and in many of the specimens their individual outline cannot be distinguished by the unaided eye.

Gold. Gold occurs in association with magnetite and chalcopyrite in the contact deposits, and with chalcopyrite and pyrite in the veins. There seems to be no relation between the amount of galena or sphalerite and the gold value. Placer gold occurs along the upper part of Mary Ann creek.

Hematite. This oxide of iron was only noted as a product of surface oxidation of magnetite and other iron-bearing minerals.

Limonite. The hydrated oxide of iron occurs as a heavy stain on the vein outcrops and on surface exposures of many of the rocks in the area.

Malachite. Stains of the green copper carbonate are widespread in the surface portions of some of the ore deposits, although seldom found at a depth of more than a few feet.

Marcasite. An iron sulphide which is very similar to pyrite but has a crystal form strongly suggestive of the orthorhombic system, is found in the Molson mine, intimately associated with pyrite. The grains are very small and seldom bounded by crystal outlines.

Pyrite. Pyrite occurs in all the deposits of the area.

Pyrrhotite. This sulphide of iron ($Fe_n S_{n+1}$) was noted in the Myers creek, Crystal Butte and Butcher Boy properties. It is never conspicuous in amount.

Quartz. This is the common gangue mineral of the vein deposits and is nearly always present in the contact area. It is generally coarsely crystallized and of bluish color.

Sericite. White mica is strongly developed as a secondary mineral in the wall rock of many of the veins and is also widespread in the granite and syenite, although present here in much less conspicuous amounts. It occurs in a fibrous felted form.

Serpentine. This mineral is limited largely to the surface exposures of regionally metamorphosed basic porphyries where it occurs as an alteration product of pyroxenes and amphiboles.

Silver. Silver occurs in most of the deposits, although never in sufficient amounts to make the ore valuable for silver. In places it seems to vary in amount with the quantity of lead, as in the Apex mine.

Sphalerite. This mineral occurs in several of the veins west of Myers creek but is never important. In all places noted it was accompanied by galena.

Tetrahedrite. A few crystals of gray copper were noted on the dump of the Olentangy shaft. It is not known at what depth they were encountered. The crystals are small, of tetrahedral form and yield heavy white fumes before the blowpipe.

Titanite. Titanite occurs as automorphic crystals and less frequently as bands surrounding magnetite. It is most conspicuous in slides from the contact metamorphic area.

Tremolite. This has the same general distribution as actinolite.

Zoisite. Zoisite is a very common associate of epidote in the contact of metamorphic area, and in many of the specimens of the regionally metamorphosed schists and basic porphyries.

CHAPTER IV.

DESCRIPTION OF PROPERTIES.

In the description of individual properties which follows it is not intended to attempt an exhaustive statement concerning any individual property, nor is it possible to include all of the properties in the district, but rather to record the more important observations made on the several claims which were visited, in order to give the studies as concrete a bearing as is possible in a reconnaissance report.

GRANT PROPERTY.

The Grant property is located on the east slope of Buckhorn mountain near the summit and about four miles on a direct line a little north of east of Chesaw, although by wagon road the distance is about nine miles. Six claims, three of which were located in 1901 and three in 1902, are included in the group. The property is owned by the Grant Consolidated Mining Company, with offices at 516 and 517 Peyton Block, Spokane. Twelve carloads of hand-sorted ore have been hauled to the railroad at Myncaster, 15 miles distant and from there shipped to the smelter. The returns ran from $22.00 to $28.00 per ton, the principal value being in copper, although two to four dollars were in gold and about the same in silver. The copper content varied from seven to nine per cent.

The workings consist of a tunnel 800 feet long and a few surface openings. The rock formations exposed on the property are the regionally metamorphosed limestones, shales and sandstones of the Paleozoic series, intruded by a quartz-bearing hornblende syenite which has caused very intense contact metamorphism, resulting in extensive zones of garnet and epidote so that certain areas have been locally called "epidote rock" and others "garnet rock." The igneous mass which caused the metamorphism is a dark bluish gray, medium grained granular rock composed chiefly of feldspar and hornblende crystals, with biotite and quartz in very subordinate amounts. Microscopically examined the rock is seen to be largely orthoclase, hornblende, quartz, and biotite with some albite and minor accessory minerals. Many of the feldspars have been partially replaced by epidote and sericite, which are developed around the margins of the crystal and along cleavage planes.

Adjacent to the igneous mass the alteration has resulted in an extensive development of garnet (grossularite) as small, clear to light green grains, which in thin sections are of four, six or eight sides, and are scattered irregularly through the slides. Calcite, residuary from the former limestone, constitutes about 30 per cent. of most of the specimens studied. Quartz locally replaces the calcite and is also intergrown with various secondary minerals. Green epidote (pistacite) occurs as prisms and grains with irregular outlines and is nearly always intergrown with zoisite which, however, never equals it in amount. Actinolite locally makes up as much as ten per cent. of hand specimen although in general it is not conspicuous and was not found in some of the slides. It occurs as needle-like crystals clustered in more or less radiating groups. Tremolite, differing from actinolite in composition only in that it contains no iron, is developed locally in small amounts. A few automorphic crystals of titanite were noted in one of the slides. Magnetite, though absent from many parts of the contact zone, is developed in places almost to the exclusion of other minerals. Chalcopyrite and pyrite are locally developed in a manner similar to magnetite, although of less quantitative importance.

The ore bodies are irregular replacement deposits in limestone and beds of calcareous shale, and although development is not sufficiently advanced to determine the extent or peculiarities of the various bodies, yet it is quite certain that future work will encounter irregularities characteristic of such deposits. Past work has met variations similar to those which will be encountered in the future. The only mass of ore which has been worked, and the one from which the shipments before mentioned were made, came from an irregular deposit 28 feet deep by 40 feet long, by 20 feet wide. Within the stope the ore was badly mixed with country rock in which contact metamorphic minerals prevailed. The ore body has no well defined strike or dip and the walls are poorly defined, there being frequent extensions out into the country rock from the main mass. Adjacent to the large stope were small bunches of ore usually connected with it by feeders but in places isolated. A tunnel 800 feet long cuts the normal position of the ore body on a level 400 feet lower, but in it no ore corresponding to the above was found. About 250 feet from the portal, however, a ledge of magnetite carrying about $7 in gold and silver, was encountered. In conclusion, it is probable that many other bodies of ore similar to the one which has been removed will be found on the property, but the irregularities which characterized it will probably also characterize them.

The mine has been worked for copper, although gold and silver totaling $2 to $7 per ton are said to be nearly always present and in about equal values. The ore is unaltered, and consists of chalcopyrite, magnetite and pyrite. Only in a few places were any of the secondary copper minerals noted. This being true, a zone of secondary enrichment with depth cannot be expected.

MONTEREY PROPERTY.

The Monterey group consists of six patented claims situated in the northwest quarter of section 24, township 40 north, range 30 east. Development consists of a tunnel 800 feet long and shaft 65 feet deep. The workings are located near the contact between the Paleozoic formations and the quartz-bearing hornblende syenite which intrudes them. The syenite has caused extensive contact metamorphism and the ores are irregular bodies resulting therefrom. Judged from the surface exposures this group lies to the west of the most intense contact metamorphic action, although the ore is similar to that in the Grant mine and the metals are said to be about the same. At this point the syenite itself seems to be more highly altered than at most other places, many of the feldspars being completely replaced by epidote, while sericite and chlorite are also extensively developed.

NIP AND TUCK PROPERTY.

The Nip and Tuck property is situated in the northeast quarter of section 23, township 40 north, range 30 east. The property is owned by John N. Evans of Bolster, Washington. The country rock in immediate contact with the ore was concealed by vegetation but in a small prospect a body of ore composed almost entirely of pyrite and chalcopyrite, and over ten feet wide, with neither wall exposed, is laid bare. The ore is said to assay $32 in gold, silver and copper combined.

MYERS CREEK MINING CO.'S PROPERTY.

The Myers Creek Mining Company own two patented claims in the southeast quarter of section 23, township 40 north, range 30 east. The principal exposure of ore is near the bottom of a deep valley which cuts across the ore body. Here an ore mass about forty feet wide is enclosed in quartzite. The ore is quite uniformly bronze yellow in color and made up of fine-grained pyrite and pyrrhotite in about equal amounts, with some chalcopyrite and magnetite. As is especially true of all deposits of similar origin, however, the size of the ore body cannot be determined from a single exposure. Whether it will increase or decrease in size with depth can only be determined by exploration, but it is altogther probable that its width will not remain constant for any considerable distance.

NUMBER NINE PROPERTY.

Number Nine Claim is situated in the northwest quarter of section 24, township 40 north, range 30 east, and is another of the claims which are located in the contact metamorphic area on Buckhorn mountain. The property is near the contact between the intrusive hornblende syenite and the Paleozoic series. The contact metamorphic action has been very intense, changing the limestone and calcareous shales of the Paleozoic into great masses of intimately associated garnet, epidote, calcite, quartz, actinolite, tremolite, diopside and magnetite with lesser amounts of pyrite, chalcopyrite and some little titanite.

NEUTRAL PROPERTY.

The Neutral property is situated near the center of the north line of section 24, township 40 north, range 30 east. Aside from several surface workings there is a tunnel 135 feet long, which throughout the last 100 feet of its extent is in magnetite. Associated with the magnetite is pyrite and a little chalcopyrite and pyrrhotite. The magnetite mass outcrops along the trail for 1,500 feet and more east and west from the tunnel, although in places it gives way to garnet and epidote rock. The property was prospected by the British Columbia Copper Company in the hope of securing a flux that would carry sufficient precious metal to pay mining and transportation expenses. Since assays gave values of only 80 and 85 cents in gold, the work was abandoned.

The prospects to the southeast from this location show successively more and more pyrite and chalcopyrite intermixed with the magnetite.

RAINBOW PROPERTY.

The Rainbow group consists of three claims in the northeast quarter of section 23, township 40 north, range 30 east. The development consists of three small shafts, and a tunnel about 400 feet long from which a little drifting has been done. The country rock is largely quartzite and schist, although some garnet and epidote rock, probably corresponding to an original thin layer of limestone, is present.

AZTEC PROPERTY.

The Aztec claim is situated in the northwest quarter of section 24, township 40 north, range 30 east. The property has a tunnel 80 feet long which is largely in magnetite with pyrite and chalcopyrite intermixed.

CRYSTAL BUTTE PROPERTY.

The Crystal Butte group is situated in the southeast quarter of section 35, township 40 north, range 30 east. Development consists of four tunnels and a shaft, two of the tunnels being over 800 feet long. The ore body is a flat-lying quartz vein enclosed in schists and quartzites which are intruded by hornblende syenite. The vein proved very irregular in width and value and has never produced sufficiently to encourage the operators in further development. Contact metamorphism does not appear to be extensive on this property but a short distance east a great magnetite zone is prospected by several open cuts. A mill was built on Myers creek by the owners of the property.

APEX MINING COMPANY.

The Apex Gold Mining Company was formed on a lease from the Ben Harrison Gold and Copper Mining Company. The latter company have six claims situated about one-half mile north of Chesaw but the Apex lease covers only one of them. Development consists of a shaft and several small surface openings. The shaft follows the ore down and is 286 feet deep on an incline of 55 degrees to the south. From the bottom short drifts extend to the east and west and a cross-cut south. The vein, which is enclosed in schists and quartzites, is very variable in width, and extensively broken by slips. In places it reaches a width of about six feet. Blue gray quartz is penetrated along the joints and crevices by fine-grained iron and copper pyrite with occasional patches of galena and blende. Separate assays of the different elements in the ore have been made and indicate that the chalcopyrite carries most of the gold, although pyrite is but little less important, with lead and blende of very minor importance. When lead predominates a little silver is nearly always present. Carefully hand-sorted the ore is said to run about two ounces of gold per ton.

A mill, equipped with rolls and Frue-vanners, which is capable of handling about ten tons of ore per day, is in connection with the property.

BUTCHER BOY PROPERTY.

The Butcher Boy group comprises two claims situated in the northwest quarter of section 21, township 40 north, range

80 east. Eleven carloads of ore have been shipped from the property and the returns from these have been sufficient essentially to pay for the development, which consists of a tunnel about 400 feet long and a shaft connecting with it. The vein, which is an irregular fissure deposit varying from a stringer up to several feet in width and striking north 50 degrees west and dipping 74 degrees northeast, is enclosed in rocks of Paleozoic age. Both limestone and clastic formations are present but the predominant type is a fine-grained basic porphyry thought to be interbedded with the Paleozoic sediments. The ore is white to cream colored quartz-bearing pyrite, pyrrhotite, sphalerite and galena. The pyrite in most instances is distributed as ribbons in the quartz, although isolated cubes and aggregates of cubes were noted in a few places. Pyrrhotite is very common and in places represents the entire mineralization. Its occurrence is very similar to pyrite. Sphalerite, or blackjack, is usually present but galena is rare. Gold is chiefly in the pyrite of massive blotchlike form, although the cube form is not altogether barren. The heavy pyrite ore carries from one to five ounces in gold per ton.

MOLSON GOLD MINING CO.'S PROPERTY.

The Molson Gold Mining Company now owns the old Poland China group of claims which are situated about four miles northeast of Chesaw. Various buildings are on the property, including a mill equipped with six Nissen stamps. About 1,500 feet of development work has been done, consisting of a tunnel 436 feet long, and various shafts and cross-cuts.

The country rock is carbonaceous shale of the Paleozoic series. An analysis of this rock made by Mr. R. I. Plomert, superintendent for the company, shows the following:

SiO_2	71.00
Al_2O_3	15.60
$CaCO_3$	4.94
CaO	5.79
MgO	.65
	97.98%

The formation is badly broken by slips which, although most conspicuous in a north-south zone, run in various directions. Assays of the wall rock give returns of $.63 to $2.27 per ton in gold.

The vein runs northeast-southwest and dips 26 degrees northwest. It is very irregular, in places being some 14 feet across, while in others it pinches down to a stringer, which in many instances is offset by faulting. In places the fresh ore reaches the surface, but in others the oxidized zone extends to a depth of 18 or 20 feet. The average ore is dense blue quartz, bearing pyrite and probably some marcasite. Spots of galena occur. Gold is the metal sought although some silver is present.

The average ore of the property runs about $4.75 per ton with about one ounce silver to be added. Superintendent Plomert states that the ore can be mined and milled, according to a test made on some 300 tons, for a little less than $4.00 per ton. This estimate, however, does not allow for any dead work.

MAD RIVER MINING CO.'S PROPERTY.

The Mad River Mining Company's property consists of seven patented claims situated in sections 7 and 8, township 40 north, range 30 east. There are various open cuts and shafts on the property exposing several strong quartz veins, which in general strike 10 degrees to 20 degrees east of north. The property is along the contact between granite and Paleozoic beds. The granite is light gray in color, showing the usual association of crystals for a granite, plus some pyrite and intrudes schist, quartzite, greenstones and some limestone. In places small limestone areas have been metamorphosed but at no point noted was the action intensive or extensive.

OLENTANGY GROUP.

The Olentangy group comprises four patented claims situated in the west part of sections 8 and 17, township 40 north, range 30 east. Development consists of a shaft 160 feet deep with drifts on the 100 and 150 foot levels. The ores, which are enclosed in calcareous quartzite, occur along the brecciated zone accompanying a fault-line which strikes north 35 degrees east and dips 55 degrees southeast. A number of stringers of quartz lie in the hanging wall parallel to the main ore body. The productive vein matter is loose breccia cemented by quartz and carrying chalcopyrite, traces of gray copper, pyrite, some arsenopyrite, blende and galena. Gold, which varies in amount from traces to high grade, is the metal sought.

DELATE CLAIM.

The Delate claim is situated in the southeast quarter of section 8, township 40 north, range 30 east. Development consists of a short tunnel with drifts to the east and west totaling about 300 feet. The ore encountered has been as limited fillings along joints and fractures instead of a true lead of commercial extent. The vein minerals noted were pyrite, galena and bornite included in a quartz-calcite gangue. The enclosing rock is massive gray to slate-black quartzite.

PART II.

GEOLOGY AND ORE DEPOSITS OF THE OROVILLE-NIGHTHAWK MINING DISTRICT.

GEOLOGY AND ORE DEPOSITS OF THE OROVILLE-NIGHTHAWK MINING DISTRICT.

INTRODUCTION.

LOCATION.

The area considered in Part II of this bulletin includes six mining districts, no one of which has been assigned definite boundaries while in some instances two or more names are locally applied to the same district. For purposes of convenience in this paper the designation "Oroville-Nighthawk" has been applied to the entire area since these are the two principal towns and by their geographic position imply more accurately than the name of an individual district the scope of the territory studied.

Oroville, a little town of 500 population situated at the south end of Lake Osoyoos, is the principal settlement in the area. Nighthawk, twelve miles west of Oroville, and Loomis, about fifteen miles southwest are both small settlements, each with a postoffice and hotel. There is a small store and postoffice at Wehesville. A branch line of the Great Northern railway extending northward and westward from Spokane, traverses the area along the valley of Similkameen river. Right-of-way has been secured for an electric road along Sinlahekin creek which, when completed, will afford ready transportation to Conconully and other points south.

FIELD WORK AND ACKNOWLEDGMENTS.

Field work occupied the interval from August 4 to August 27, 1909, the mines and principal prospects being visited and examined in such detail as time permitted and a map of the general geology prepared. Through the field season the writer was ably assisted by Mr. Olaf Stromme, most of the areal geology being mapped by him. Mr. Stromme also assisted in the preparation of parts of the report. Courtesies extended by the many mining men in the area were too numerous to permit of individual mention.

EARLIER WORK.

The Oroville-Nighthawk district being a part of the area under consideration at the time of the survey of the international boundary, was visited and examined in a general way by geologists of both Canada and the United States. For the United States Messrs. George Otis Smith and Frank C. Calkins undertook, in 1901, a reconnaissance from Osoyoos Lake westward. Although the major portion of their work was topographic and connected with the examination of the boundary, yet considerable information on the general geology of the country traversed was accumulated and is recorded in a special bulletin of the United States Geological Survey. (*a*).

The work by the Canadian government corresponding to the above was carried out by Dr. Reginald A. Daly. Several articles have appeared as a result of his studies, both in the publications of the Geological Survey of Canada and in technical journals. The paper, however, having the most intimate bearing on the area herein considered is entitled "The Okanogan Composite Batholith of the Cascade Mountain System," in which Mr. Daly discusses in great detail the composition and relations of the intrusive masses of the area. (*b*)

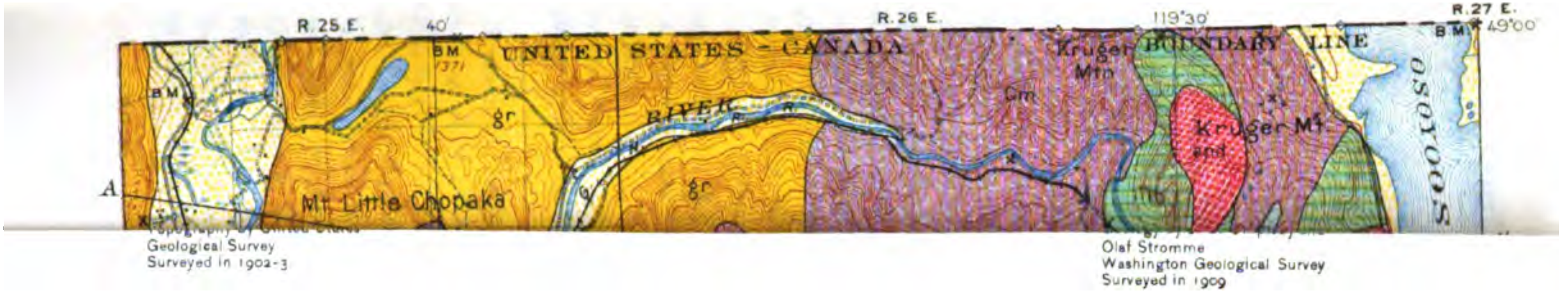
Mr. Baily Willis passed through the district in 1887, making many notes on the physiographic features. (*c*)

Reference to work in adjoining areas will be made in the text.

(*a*) Smith, G. O., and Calkins, F. C., A geological reconnaissance across the Cascade range near the forty-ninth parallel. Bull. U. S. Geol. Survey No. 235, 1904.

(*b*) Bull. G. S. A., Vol. 17, 1906, pp. 329-376.

(*c*) Willis, Bailey, Changes in river courses in Washington territory due to glaciation. Bull. U. S. Geol. Survey No. 40, 1887.



GEOLOGIC MAP OF OROVILLE-NIGHTHAWK DISTRICT

BY JOSEPH B UMPLEBY

ASSISTED IN THE FIELD BY OLAF STROMME

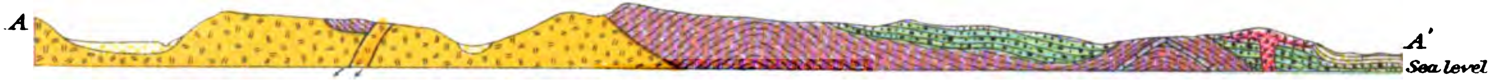
Scale

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.

Datum is mean sea level.



SECTION ALONG *A-A'*

CHAPTER I.

PHYSIOGRAPHY.

GENERAL STATEMENTS.

The Oroville-Nighthawk district is situated in Okanogan county, and comprises the northeast part of the Chopaka and the northwest part of the Osoyoos quadrangles, as mapped by the United States Geological Survey. It is from six to thirteen miles in length by seven to fifteen miles in width, the international boundary forming its northern border.

The area mapped is embraced in that physiographic division of the state known as the Okanogan highlands and is characterized by deeply dissected land forms. Elevations range from 922 feet above sea level at Oroville, to 7,829 feet at the summit of Mt. Chopaka, although 3,500 to 4,000 is about the average altitude; with the larger inter-mountain valleys varying in depth from 2,000 to 2,800 feet. The sharpest transition from lowland to highland within the area is that from the floor of Similkameen valley to the south summit of Mt. Chopaka, where there is a rise of about 6,200 feet in a horizontal distance of two and one-third miles. Such slopes, however, are rare in the area, the rounded forms predominating. In general the district is a rolling upland rather deeply gashed by the valleys which drain it.

Prominent valleys divide the district into several distinct divisions chief of which are the Mt. Chopaka division, the Mt. Elemeham-Palmer Mountain division, and the Mt. Little Chopaka-Kruger Mountain division. The presence of these mountain areas, in contrast to the intermontane valleys, seems to be due largely to stream courses which antedate the present topographic cycle rather than to differences in rock resistance or to structure. Roughly, the Okanogan valley forms the eastern boundary of the area, the Similkameen the northern boundary, the valley of Sinlahekin creek and of the Similkameen the western boundary, and Spectacle lake valley the southern boundary. The most interesting one of these is that along the western side of the area. This valley, although occupied in one part by a river, in another by a lake and in a third by a small creek flowing in a direction opposite to that of the river, is of almost constant width and about uniform depth. It continues south for many miles but within the area studied are two cross depressions of much less striking characteristics, which connect it with Okanogan valley to the east. One of these is at Loomis and the other along the course now occupied by the Similkameen river east of Nighthawk. The east-west depression joining the main valley at Loomis has a flat from one-fourth to one-half mile wide, giving way by gentle slopes and comparatively low cliffs to the higher country north and south. Spectacle lake, a narrow body of water two and one-half miles long, occupies the valley about half way betwen Loomis and the Okanogan river. The valley extending east from Nighthawk is steeper and more gorge-like in the east two-thirds of its extent than the one just described, but in the section near Nighthawk there is a narrow flat on each side of the river and the stream is sluggish.

Mr. Bailey Willis made a reconnaissance through the area in the later eighties and in the resulting publication* suggests that the Similkameen river formerly flowed south through the large valley first described, joining the Columbia at some point south of Conconully. In the Pleistocene period a great stream of ice occupied the valley, and deposited vast quantites of materal upon its floor. During the general ice recession there were several places where the waters from the glacier found lower outlets to the east than over the glacial debris to the south. Spectacle lake is thought to be one of these outlets and it is probable that it carried the waters from the ice front after it had retreated to a point above Loomis, and until it stood in the vicinity of the Canadian boundary, when it became possible for the stream to take its present course to the north. The general topographic relations suggest that the present course of the river east of Nighthawk is due to piracy in post-glacial time by a stream working headward from near Oroville, but this is considered improbable as fine terraces of stratified drift occur at various places in the valley near the level of the river. Since the section of this valley near Nighthawk is broad and open, with a sluggish stream, while that part near Oroville is narrow and carries rapidly moving waters, the most feasible explanation of the relation seems to be that, in pre-glacial times, this valley was occupied in its eastern part by a tributary of the Okanogan and in its western by one of the Similkameen, the intervening divide being low. After the ice front had retreated to some point to the north, the waters escaped eastward over the divide due to the damming of the main valley to the south and the course has been held since that time.

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*Willis, Bailey, United States Geological Survey, Bulletin No. 40, 1887.

Within the area mapped evidences of glaciations were seen at all altitudes visited. Striations, even when on the east and west slopes of the mountains* have a north south direction. This nullifies the possibility of local centers of radiation on the higher areas, and leaves no room for doubt that the ice which covered the area was the southward extension of the Cordilleran ice sheet which radiated from the highlands of British Columbia.

The soils of the valley floors are alluvial, while those of the terraces and benches bordering the valleys are glacial and in some cases partly alluvial. The valleys are all treeless in their natural condition, the vegetation consisting of sagebrush and greasewood, largely the former.

The area covered by this report is rather sparsely settled, and the inhabitants are engaged in agriculture, horticulture, stock raising and mining. The valleys require irrigation, as the rainfall is light, but when watered the soil will produce in great abundance any crop grown in the temperate zone; particularly apples, pears, small fruits and vegetables. Horticulture is in its infancy, however, and very little land is now under irrigation. There are a few places which are irrigated from creeks and in a few cases pumping plants have been installed, but no large irrigation canals have been attempted. On the uplands, up to an elevation of 3,000 feet or more, wheat, oats, and the hardier vegetables are successfully grown and yield abundantly, without irrigation. The bunch grass land of the higher altitudes is well adapted to grazing and there is still some open range, but owing to the altitude, the season is too short and the nights too cold for successful raising of crops.

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*Mt. Elemeham, west slope at elevation of 4,600 feet shows small area of bedrock with striations running north 11 degrees west.

The mining industry furnishes employment to a considerable number of men during much of the year, more in the carrying on of development and assessment work, than in the mining of ore.

Lack of adequate transportation facilities has been one of the chief drawbacks to the development of the area. Oroville, the principal town, is situated on a branch line of the Great Northern railway, as is Nighthawk, one of the smaller towns. Loomis, in the southwest part of the area, is reached by stage from Nighthawk or Conconully. The Oroville branch of the Great Northern railway follows the Similkameen valley from Oroville to Nighthawk, and then extends northerly up the valley into British Columbia. The area has a fair system of wagon roads, the principal ones following the valleys and having easy grades.

On the Similkameen river, about three miles northwest of Oroville there is a hydro-electric plant where approximately 600-horse-power is developed from a natural fall in the river, only a small portion of which is diverted. The current is transmitted to Oroville, and to the more important mines of the district. It is safe to say that less than ten per cent. of the power available on the Similkameen in Okanogan county has been developed, and it would seem that with an ample supply of water, such as exists in the Similkameen and Okanogan rivers and in Osoyoos and Palmer lakes, there ought to be an excellent opportunity for supplying cheap electric power for pumping water onto the bench lands.

It is probable that all the physiographic features of the area are post-Eocene and perhaps post-Miocene and had reached the stage of maturity which is characterized by approximately equal areas in upland and lowland flats, in other words, by a maximum of slope, before glacial times. The ridges were narrow, the slopes steep and the valleys deeply carved and "V-shaped." In the Pleistocene the cycle was interrupted by deposition of a mantle of drift on the uplands, the partial filling of the valleys with glacial material and resulant choking of the drainage system. Many closed basins were formed and in some of them lakes exist throughout the year. As would be expected in an area of heavily mineralized and heterogeneous rocks, these lakes being without outlet, and therefore subject to a constant concentration of impurities in the water by evaporation, contain a high percentage of mineral matter. The precipitates from some of them have been exploited recently but with what success is not known.

CORRELATION OF EROSION PERIODS.

The area herein described does not have that general accordance of summit levels which is very evident from a point of vantage in most parts of the Okanogan country. If its topographic cycle is to be defined, recourse must be made to records in adjoining regions. But there, as will be seen beyond, difficulties are encountered due to difference in age of the erosion surface known to the west and southwest and that occurring to the north and east.

G. M. Dawson* recognizes a peneplain in the interior plateau of Canada, remnants of which stand at elevations of from 4,000 to 6,000 feet above sea level, in the southern half of the interior plateau of today. The evidence for the Eocene age of this surface is the presence of Miocene beds in great valleys developed in it and the broad fact that extensive Eocene deposits are found in adjoining physiographic areas to the south while none are found here, which seems to imply that the area was land during the Eocene period.

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*Dawson, G. M., Trans. Royal Society of Canada, 1890, p. 11.

In the Republic area (*a*) to the east an erosion surface was recognized and on the strength of fossiliferous beds so related as to be fairly conclusive, was assigned to the Eocene.

South of the area herein mapped, however, Bailey Willis (*b*) found that the oldest erosion surface recorded, the Methow stage, is cut on all rocks of the region including "the bedded basalt flows and the pumiceous clastics of the Ellensburg formation, which is known definitely to be of the Miocene age."

It appears therefore, that the old physiographic surface to the north is Eocene while that to the south is post-Miocene.

In a reconnaissance across the Cascade mountains along the forty-ninth parallel, Smith and Calkins (*c*), recognize this relation, for in referring to the physiographic differentiation of the Cascade mountains they write in part as follows:

"An example of this is found in the occurrence of an Eocene peneplain in the interior plateau region, while in the Cascades peneplaination of Eocene age has not been recognized, and indeed in central Washington the Miocene lavas are known to rest upon a surface possessing considerable relief."

Within the area represented by the present map the former erosion surface has been so destroyed that it is of little value for purposes of age determinations. All the older rocks, including the Similkameen batholith at least in its eastern part, have been beveled by it. Lake beds found west of Oroville and evidently occupying a post-peneplain depression, did not yield fossils, but in their lithologic characteristics and the association of andesite flows with them, they resemble very strongly the Miocene beds at Republic. These facts, together with the known occurrences of Miocene lake beds in British Columbia, suggests that this part of the area belongs to that physiographic unit known as the interior plateau of British Columbia;

(*a*) Umpleby, J. B., Washington Geological Survey, Bul. No. 1, pp. 19-20, 1910.

(*b*) Smith, G. O., and Willis, Bailey, U. S. Geol. Survey, PP. 19, pp. 17-71.

(*c*) Smith, G. O., and Calkins, F. C., U. S. Geol. Survey, Bul. 235, p. 90, 1904.

and if so, was peneplained in the Eocene period. Mt. Chopaka in point of elevation seems to correspond better with the post-Miocene surface to the west and may belong to the Cascade unit. If this relation is true the line of union of the Eocene and post-Miocene erosion surfaces will probably be found, within the present area, to approximately follow the Similkameen-Sinlahekin depression.

CHAPTER II.

GENERAL GEOLOGY.

BRIEF STATEMENT OF GEOLOGIC HISTORY.

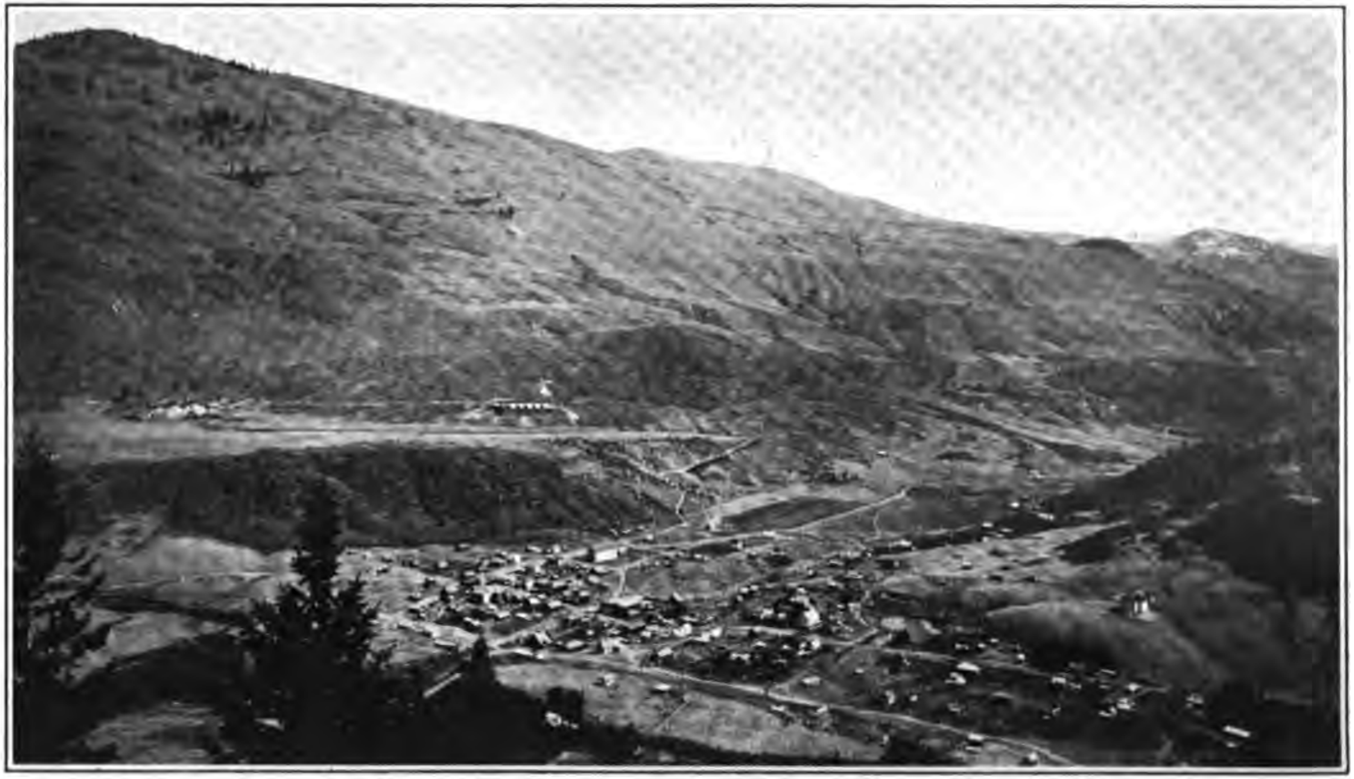
The broader features of the gologic history of the Oroville-Nighthawk area include sedimentation accompanied by igneous activity in the Paleozoic, with regional movements and resulting metamorphism about its close; erosion, and great batholithic intrusions, in the Mesozoic; planation in the early Tertiary, followed by elevation and erosion, the accumulation of lake beds and lava flows; and erosion and continental glaciation in the Quaternary.

The oldest rocks exposed in the area are the metamorphic equivalents of shales, sandstones, limestones and intrusive and extrusive basic igneous rocks, all of which appear to have been subjected to the same period of structural movements and regional metamorphism. On lithologic grounds this series is tentatively correlated with the Cache creek series of British Columbia which is Carboniferous. Intruded into these older rocks is a great granite batholith which, since it does not show evidences of diastrophic movements is thought to be of Mesozoic or early Tertiary age. Early in the Tertiary it is probable that the area was reduced to near base level, then elevated and extensively cut by erosion, lakebeds accumulating in some of the resulting valleys. Following the lakebeds and in part contemporaneous with them were local eruptions of andesite. In the Pleistocene a southward extension of the Cordilleran ice sheet covered the entire area, leaving a heavy mantle of glacial drift and profoundly influencing the drainage system.

PALEOZOIC SERIES.

Distribution.

A great series of rocks which has been assigned to the Paleozoic is widely distributed in the south and central part of the area and extends in a narrower belt west to Mt. Chopaka and



Loomis, from the southwest. Palmer Mountain in background and to left. Spectacle Lake and Valley extending to the right.

north to the international boundary, while west of Lake Osoyoos are three more or less isolated areas of the same formation.

Characteristics.

The series as a whole is notably but not intensely metamorphosed. Distinct bedding is seldom seen although foliated schists, quartzites presenting complete recrystallization, and even marble are rare and were not noted save in the vicinity of intrusive masses. On the other hand slaty cleavage and jointing are common. Intimately associated with this series are basic lavas, pyroclastics and intrusions.

The various types of rock present in the series were not differentiated on the map since to do so would have required far more time than could be given to the reconnaissance. The limestone areas are fairly conspicuous in the field and were sketched in order that the structural relations might the better be portrayed by the map.

Broadly speaking the series consists of three divisions, which beginning with the oldest are: (1) dark gray to greenish black thinly laminated clay slates and siliceous schists with occasional quartzite bands; (2) blue limestone with interstratified clay slates and siliceous beds; (3) siliceous and argillaceous beds with a great deal of interbedded igneous material.

The lower part of the series is exposed best in the central part of the area, Mt. Ellemeham being perhaps its type locality. The rocks as here found are dark gray, reddish brown and occasionally green siliceous schists and mica bearing clay slates. They are thinly bedded and very fine-grained. The beds are extensively jointed and in a few places slaty cleavage is more pronounced than the bedding. They strike north-south and dip 40 degrees to 50 degrees west. The thickness of this portion of the series is not known but it is by far the most important division and gives the impression that its thickness must be thought of in thousands rather than hundreds of feet.

The middle division of the series outcrops between Kruger mountain and Osoyoos lake and from there the surface exposure swings southwest, having an extensive development a short distance west of Golden, whence it extends southeastward beyond the limits of the area mapped. The division consists of irregular lenses of blue limestones included in clay and siliceous beds which, save that they are more massive and in places finely conglomeratic, are not very different from those of the underlying division. The limestone weathers to a light gray which is in sharp contrast to the dark shades of the enclosing schists and slates, causing areas of it to stand as striking features in a general survey of the landscape. Closely examined, the rock is seen to be fine-grained, extensively crushed and locally partially converted into marble. In many places the bedding planes are still intact so that dip and strike can be measured easily. Usually the contact of the limestone with the enclosing schist is sharp but in places perfect gradation between the two occurs.

A remarkable characteristic in the limestone areas of this region is their irregularity in shape and the manner in which they pinch out along the strike. In general they are roughly lenticular but no general ratio exists between their areal extent and their thickness. There are two general horizons of these limestone lenses, separated by 200 feet to 400 feet of clay slate. In the upper horizon the lenses appear to be more numerous and it was here that the maximum thickness, 200 to 300 feet, was measured.

Time did not permit a careful study of the limestone beds but certain facts were noted which seem to have a bearing on their origin. There are apparently three ways in which they may have assumed their present peculiarities: (1) by the crushing together of more widely distributed beds; (2) by faulting; (3) by reason of special conditions of deposition. Considering the three alternatives in the order above named, it appears that the general preservation of bedding planes within the limestone refutes the first. Concerning the second, faults sufficient to account for the relations were not noted in the field and indeed would not be expected since they would be out of harmony with the general structure of the region. By elimination therefore, it is suggested that the limestone areas may be due to special conditions of deposition such that the lenses now have essentially their original outline and geographic distribution.

The upper division of the Paleozoic series which contains large quantities of volcanic material is extensively developed on the south end of Palmer mountain, on the hill southwest of Palmer lake, and in the general area east of Loomis. Although the igneous material is far more conspicuous than the sedimentary in this part of the series, yet considerable beds of sediments are present, as can be seen in a traverse from Loomis up over the mountain to the vicinity of Ivanhoe mine. Along this course several areas of dark greenish black slate appear and are in contrast to the rusty black basaltic material. In places the two are scarcely distinguishable and close examination suggests that the rock is made up both of small angular pyroclastic fragments and sedimentary material.

The most striking exposures of these old volcanic beds is in the south wall of the valley which extends east from Loomis. Here, when seen from a distance, the beds have every appearance of basaltic flows, rough columnar jointing, and massive forms being very pronounced. Closer examination reveals a fine-grained rock, in places having scattered phenocrysts in a dull lustered ground mass; in others a decided brecciated appearance; and yet again being a mass of small angular volcanic fragments roughly intermingled with sedimentary detritus. Microscopic study of the specimens gathered is unsatisfactory in that alteration has universally progressed so far that the minerals essential in classification cannot be definitely determined. The few feldspar crystals which are sufficiently fresh for identification have about the composition of andesine. Outlines of some pyroxene mineral are usually present, as is also hornblende, magnetite, and a little quartz. From the few feldspars which were determinable together with the pyroxene and magnetite, it seems that the rock is a basic andesite, although the general texture is that of basalt.

In part the brecciated character of the formation in many exposures may indicate pyroclastic origin but it might also be due to the sudden cooling of lava poured out beneath water and since the sedimentary part of the series was very clearly deposited in water, the latter view seems more probable.

Age.

Fossils were not found in the area but the general lithologic make-up of the series corresponds very closely to the Cache creek series which Dawson has described and which has yielded fossils of Carboniferous age. (*a*).

GABBRO OF PALMER MOUNTAIN.

An area of greenish black granular rock comprises the southwest slope of Palmer mountain and extends across Sinlahekin creek valley and a short distance up on the west wall. The boundaries of the area are difficult to trace since in many places the contact is with the basic lavas of the Paleozoic series, which are closely related in composition and general appearance. Indeed it has been suggested that this may be one of the centers from which the lavas poured. (*b*)

The rock has a marked ophitic structure and is made up essentially of feldspar and hornblende. The feldspar seems to correspond to a basic andesine in composition. A little quartz is usually present and frequently encloses minute needles of hornblende. Outlines and occasional remnants of some monoclinic pyroxene appear in specimens from near the summit of Palmer mountain. Olivine was not noted. Calcite, biotite, zoisite and green epidote as well as much of the hornblende, are secondary.

(*a*) Ann. Rept. Geol. Survey, Canada, new ser., vol. 7, 1894, pp. 37B-49B.

(*b*) Smith, G. O., and Calkins, F. C., A geological reconnaissance across the Cascade range near the forty-ninth parallel. Bull. U. S. Geol. Survey, No. 235, 1904, pp. 46-47.

SIMILKAMEEN GRANITE.

Distribution.

The Similkameen granite, so designated by Daly (*a*) occupies the northwest part of the area mapped. It is deeply trenched by Similkameen river from a point five miles below Nighthawk westward to the international boundary. South from Chopaka mountain the granite appears at intervals along the entire western limit of the area mapped. A noteworthy occurrence of the same or very similar rock is as small patches near Golden and between that place and the main granite area to the north.

Characteristics.

The Similkameen batholith (*b*) is composed of medium to coarse grained light gray granite. It varies in composition from place to place, biotite and hornblende being the chief variables, the former nearly always present but in different amounts, while the latter is frequently almost absent. Marginal variations are pronounced, quartz decreasing very markedly in amount while the ferromagnesian constituents become much more abundant. This marginal basification is so pronounced north of Loomis that specimens from near the contact would readily be classed as diorite save for the absolute gradation into the normal granite. Texturally the granite varies from equigranular to strongly inequigranular, while in places, as near Golden, the orthoclase has a strikingly phenocrystic development.

Microscopic examination shows that the average specimen consists of the following essential minerals decreasingly important in the order named: oligoclase, microperthite, quartz, orthoclase, biotite, microcline and hornblende. Magnetite, beautifully developed titanite, apatite, and occasionally zircon are accessory.

(*a*) Daly, Reginald A. The Okanogan Composite Batholith of the Cascade Mountain System, Bull. G. S. A., Vol. 17, 1906, p. 234.

(*b*) This granite is described by Daly, op. cit. pp. 452 to 454; and by Smith and Calkins, op. cit. pp. 32-33.

Age.

The age of this granite batholith is uncertain since there is no sedimentary record from the close of the Paleozoic until well on in the Tertiary. Daly (*a*) notes the lack of schistosity in the granite and takes this to mean that the intrusion post-dates the orogenic movements which Dawson recognizes throughout the Canadian Cordilleran and assigns to the close of the Laramie period. (*b*) Thus Daly believes the intrusion to be early Tertiary. In this connection it is perhaps significant that extensive faulting within the granite and which seems to be of the reverse type, occurs along the east face of Chopaka mountain while normal faulting appears in the area just west of Nighthawk.

On the other hand there is considerable reason for thinking that the area was peneplained in Eocene times, meaning thereby that comparatively static conditions then prevailed. Since, therefore, the granite was beveled by Eocene erosion, as discussed in the chapter on physiography, if it be assigned to the Tertiary it must be assumed that it was intruded during a period of diastrophic inactivity.

In view of these general considerations and since the faulting above referred to may be a local expression of the movements which closed the Laramie period it seems very possible that the granite is of pre-Tertiary age, preferably late Cretaceous.

TERTIARY ROCKS.

LAKE BEDS.

Extent.

Lake beds occupy an irregular area of about fifteen square miles lying north and west of Oroville. The general outline of the deposit is very irregular, due both to the encroachment of younger lavas and to the relation of the older metamorphics, a pronounced arm of which extends southward from east of Kruger mountain into the general area of lake deposits. From other known areas beyond the limits of the district mapped it is

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(*a*) Op. cit. pp. 360-361.

(*b*) Bull. Geol., Soc. Am., Vol. 12, 1901, p. 87.

known that the formation is confined to a north-south zone, never over a few miles in width.

Description.

The Tertiary beds have suffered considerable deformation, in places presenting dips as high as 30 degrees. The strike is usually north-south in the northern part of the area and more nearly east-west in the southern, being directions of dip such as would correspond to an irregular anticline-syncline structure.

The beds are well exposed in the valley of Similkameen river where their unequal resistance to erosion gives steep bluffs along the valley sides and low falls and rapids in the river. In the bluffs sandstones and coarse and fine conglomerates are exposed, much of the latter being very angular and composed of fragments of metamorphic material and granite similar to the basement series of the region. The beds in the western extension of the area are largely composd of granite blocks with arkose filling the interstices, while the southern extension mostly presents detritus derived from the metamorphic series. In nearly all localities examined tuffaceous andesitic material was noted. This general composition suggests a very local derivation of the material, that in the west extension coming primarily from the adjacent granite, while to the south the metamorphic series was the chief source of supply. The andesite tuff was probably in part deposited directly in the lake and in part washed into it from the surrounding country.

The thickness of the formation could not be satisfactorily measured in any of the exposures visited but it will likely not be far amiss to think of it as 500 feet.

Age.

Fossils were not found in these beds but their lithologic character and topographic relations closely resemble the Tertiary deposits at Republic, (*a*) 45 or 50 miles farther east, which are placed as Miocene on the strength of fossil evidence. (*a*) The points of analogy are that both deposits contain much an-

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(a) Umpleby, J. B., Geology and ore deposits of Republic District, Washington. Wash. Geol. Survey, Bull. 1, 1909, pp. 24-25.

desitic tuff and both are followed by andesite flows. Furthermore, beds of Miocene age have been reported from many of the larger valleys of British Columbia (*a*) while beds of Eocene age are absent and Pliocene lakes if reported are unknown to the present writer.

Since Miocene lake deposits are known at various places in the boundary country, while beds assigned to other divisions of the Tertiary are not common, if occurring at all, and since the analogy with the Republic deposits is so close, it would seem reasonable, even in the absence of fossils, to consider the lake beds at Oroville as Miocene.

ANDESITE.

Distribution.

Three areas of andesite occur in the Oroville-Nighthawk district. The largest comprises about one and one-half square miles and is plastered against the steep slope west of Oroville. The next in importance forms the capping of Kruger mountain, while the third appears in the valley wall west of Lake Osoyoos.

Characteristics.

The andesite is dark gray with phenocrysts of hornblende and feldspar rather closely spaced in a dense groundmass. The microscope shows the groundmass to be imperfectly crystalline and imbedded in it are crystals of andesine, hornblende, and a little oligoclase. Magnetite is accessory.

The flows rest unconformably on the lake beds but the amount of erosion which occurred between them is not important in comparison with post-andesite erosion. This probably means that the andesite eruption followed rather closely the formation of the lake beds.

QUATERNARY HISTORY.

Glacial drift appears at all altitudes within the area and in many places grooved and polished bedrock may be found. The striations in general indicate that the ice advanced from

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(*a*) Dawson, G. M., Trans. Royal Soc. of Canada, 1890, p. 12 *et al.*

about five degrees west of north. This direction of motion is clearly recorded on both the east and west slopes of Ellemeham mountain near its summit, thus obviating the possibility of local centers of radiation and leaving little room for doubt that the area was covered by a southward extension of the Cordilleran ice sheet. Further evidence of continental glaciation is the rounded and smoothed contour of the north-south valleys while the east-west ones are rough in outline and nearly always present a very heavy and hummocky accumulation on the north wall while that on the south is much less pronounced.

The influence which glaciation has had on the general drainage of the area is considered in the chapter on physiography.

The general structure of the Cascade mountains at the forty-ninth parallel has been described as a synclinorium (*a*) and the present area may well be considered a segment of this broad structural feature. The general strike of the formations are north-south, varying rather more to west of north than otherwise. An east-west section therefore, such as the one which accompanies the geologic map, gives in its broader features the structure of the area. Several small anticlines and synclines appear but they are seldom tightly compressed, dips of about 45 degrees being the rule.

Faulting is shown in the section but it is thought that it is far more prevalent than is suggested by the map. A pronounced fault follows the east face of Chopaka mountain and dips west at 45 degrees. It seems that the west side of the fault moved up relative to the east, both by reason of the steep scarp-like mountain face which lies immediately west of the fault and because the sedimentary cap still covers the granite in places on the east while it has long been removed from the area to the west. Another reverse fault was noted north of Oroville and is described in the notes on the Golden Chariot property. Normal faulting was noted on Little Chopaka mountain where, with a

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(*a*) Smith and Calkins op. cit., p. 84.

fault plane dipping west, granite on the east is in juxtaposition with metamorphosed sediments on the west. (*a*)

The great granite mass so prominent in the geologic history of the area does not seem to have had a pronounced influence on the structure of the rocks it entered. Faulting probably preceded it but those which are mapped affect the granite and hence are later. The lakebeds overlying all other formations, save the andesite, are folded to some extent but so far as noted are not faulted.

(*a*) Further notes on this fault appear in connection with the Little Chopaka group of mining claims.

CHAPTER III.

ECONOMIC GEOLOGY.

LOCATION AND CONDITIONS.

The Oroville-Nighthawk area includes six or seven mining districts situated in northern Okanogan county. As is generally true in this region, none of the districts are organized. The accompanying map includes a general area over which exploration has been more or less uniformly pursued and which is rather definitely separated from adjoining territory where mineral deposits have not been reported.

The district presents rough and mountainous features in the western part, while in the central and eastern portions bold, rounded hills and mountains, are the characteristic forms. The inter-montane valleys are deep and in much of their extent, steep-sided. Although the streams usually have very low gradients, yet in places, notably on the Similkameen river a few miles above Oroville, rapids and low falls afford abundant water-power to supply the entire district with electricity for all purposes which are at all likely to develop.

Scattered timber occurs on most of the area, while a few miles back in the mountains to the west, abundant supplies are available. Roads follow all the larger valleys and extend into some of the upland country, while the topography is such that others can be built at comparatively low cost to most points in the area if need for them exists. Communication with the outside is afforded by a branch line of the Great Northern railway which enters the district at Oroville and thence follows the course of the Similkameen river to a point in British Columbia.

HISTORY AND PRODUCTION.

The district is one of those which attracted the prospector during the period when placer excitement was waning in California and searchers for gold were reaching out into other parts of the west. As far back as 1859 placers were worked on Similkameen river. Quartz lodes were recognized at that time but no known locations were made. Shortly thereafter the territory was set apart as an Indian reservation and the land withdrawn from mineral entry. Upon being reopened in the late nineties numerous locations were made and extensive promoting schemes inaugurated. Many of these early companies have had disastrous histories. Some were obviously born of ignorance and fostered by deceit, while others simply assumed the chances of legitimate prospecting and for one reason or another, lost. Many of the properties had excellent ore in the oxidized zone, which is very shallow throughout the area, but were unable to handle the lower grade pyritic material encountered below. Again, in many instances, the veins did not extend to the lower levels reached by long and expensive tunnels.

The actual total production of the district is not known, but it is probable that it does not exceed $1,000,000. This figure allows about $500,000 for the placers on Similkameen river, which cannot be verified. About $150,000 is ascribed to the Pinacle mine, while the remainder is from various properties, chief of which are the Black Bear, Triune and Golden Zone. The area has been primarily a gold district, although some silver and very minor amounts of the base metals are included in its production. It is possible that in the future this order will be reversed.

GEOLOGIC RELATIONS.

Broadly speaking the rocks of the area constitute a great series of metamorphosed shales, quartzites, basic lavas and tuffs, all of which have been cut in late Mesozoic or early Tertiary times, by a great batholith of soda-rich granite. Later, lake deposits accumulated and after them andesite flows spread over the eastern part of the district.

The ore deposits cut the granite but are presumably earlier than the lake beds, since in no place are they included in them.

ORE DEPOSITS.

The ore deposits fall into two general classes: (1) those in which the metallic mineral or minerals are rather evenly distributed through the rock formations, or disseminated deposits, and (2) vein deposits.

DISSEMINATED COPPER DEPOSITS.

Distribution.

Disseminated copper deposits are known a few miles west of Oroville. Development is not extensive, consisting of a few diamond drill bores and small open cuts. The principal property is known as the Kelsey group.

Characteristics.

Within the mineralized ground which comprises an ill-defined area of several hundred acres, copper stains appear on nearly every bluff and in some instances can be seen very clearly from a distance. The malachite and azurite, however, are very superficial so that within a few inches of the surface they give way to the chalcopyrite from which they are derived. This primary mineral occurs as fine grains scattered irregularly through the various rocks and as films along joints and fractures. Yet again, it is included in small quartz veinlets which cut the formations. In places rather strong quartz veins appear, as on the Golden Chariot claim, but these are not the rule.

The rocks impregnated are metamorphosed shales, quartzites and basic volcanic material. All are mineralized but perhaps the shales to a greater extent than the others.

An important feature in connection with the deposits is the occurrence of the primary minerals, chalcopyrite and pyrite, within a few inches of the surface, even where the surface alteration appears to be most intense. This relation clearly indicates that if the deposits are ever worked it will be for primary sulphide ore. A secondary zone of chalcocite enrichment, such as constitutes the ore body at Bingham, Ray and other camps of the southwest, cannot reasonably be expected here.

Just what the rock will assay on an average working basis is not known. A few diamond drill bores have been put down on the Kelsey group, but these are not in sufficient number to prove or disprove a workable body of ore.

Genesis.

The genesis of these disseminated deposits is obscure. The presence of occasional veinlets and stringers which cut the formations indicates that, in their present form at least, they are younger than the formations enclosing them, and since they disappear beneath the lake beds, they are pre-lacustrine. It appears therefore that they are to be assigned to some part of that great lapse of time to which the intrusion of the Similkameen batholith dates. Since such a deposit seems to necessitate very intense conditions whereby mineral-bearing solutions not only followed joints and fractures, but penetrated to the more impervious portions between them, a genetic relation between the great granite magma and the ore deposition strongly suggests itself. If such a relation is true it yet remains to determine whether the magma supplied the metals, or simply made possible their concentration (by heating the ground water and supplying it with solvents) from a more disseminated state in the older rocks. Evidence on this point was not sufficiently definite to be of value.

VEIN DEPOSITS.

Distribution.

Veins are widely distributed in the area but are specially developed around Nighthawk, Golden and on Palmer mountain. Those at Nighthawk strike predominantly north-south and dip west, while in the other locations no regularity in strike and dip was recognized. The strike of the several veins measured in the entire area have been plotted in a circular diagram (Fig. 3) which brings out a slight predominance of north-south directions, but were a half-dozen veins in the northwest corner of the area not considered the distribution would be remarkably regular throughout the 360 degrees.

Metals Represented.

Gold, silver and copper are the chief metals derived from the veins although lead and a little zinc are very commonly present. In the past gold has been the chief product but present development strongly suggests that silver and copper may soon vie for first place.

Types of Veins.

Two distinct types of veins occur within the area, but since all gradations between them were noted, it does not seem wise to treat them separately. The two types are tabular in form and both are properly to be classed as veins. In one the transition from vein matter to wall rock is sharp, while in the other it is so gradual that within the limits of perhaps a foot or more it would be difficult to locate the point of contact between vein and wall. In the former, mineralization is confined to the vein, while in the latter it extends out into the wall rock. The

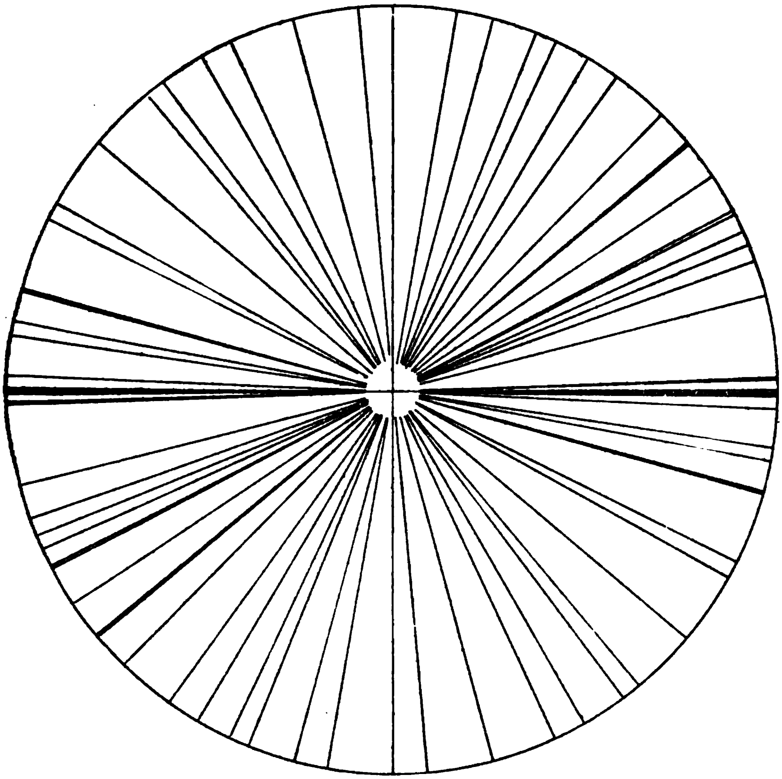

FIG. 3.—Graphic illustration of strike of the veins in the Oroville-Nighthawk District.

first are usually more regular in outline than the second. The Triune mine illustrates the former class, while the Copper World Extension belongs to the second.

Again, the veins of the district might be classed according to whether or not they occur along a fault of considerable throw. Many of the north-south lodes near Nighthawk are along faults, some of which probably have throws of several hundred feet. The deposits near Golden and on Palmer mountain nearly all show slickensides and groovings but in these there is no evidence of appreciable displacements.

It would further be possible to class the veins according to the chief minerals for which they are worked if the percentage of different constituents from various parts of the area were known better.

In general the vein matter is coarse, crystalline quartz with metallic minerals distributed as small aggregates, which in places are zonally arranged and in others more or less completely isolated. Within the same vein the kind of minerals frequently varies from place to place. Pyrite is nearly always present where any mineralization has occurred. Chalcopyrite usually accompanies it, as does also galena and occasionally zinc blende. Gold occurs free, and also included in pyrite, chalcopyrite and galena (see description of Hiawatha mine). Silver is principally as argentiferous galena, proustite, pyrargyrite, stephanite, argentite, and cerargyrite.

Depth to Which Veins Extend.

Any attempt to suggest the depth to which the veins extend in an area so little known, must be very vague, but there have been so many disappointments in this district, where long tunnels have been driven to intersect a vein far below its outcrop, that those relations which have a bearing should be pointed out. The Similkameen and its tributary valleys exist as deep, opencuts through the area. Glaciation has so worn and polished them that in many places the sides are almost free from detritus and afford excellent sections of many of the veins.

The valley sides south of Nighthawk present many quartz veins near their rim, but few of them extend over a quarter of the way down the sides and only two were noted (southwest of Palmer lake) which reach the lower slopes. While it is not safe to generalize on the strength of these observations, yet they are considered sufficiently potent to emphasize the advisability of following the ore to lower levels rather than resorting to long tunnels. The history of the district amply bears out this suggestion.

Age and Genesis.

The ores are in part enclosed in the granite but nowhere are known to cut the lake beds. Hence they seem to be confined to that period between the intrusion of the granite magma and the lacustrine deposition. Since the granite is probably late Cretaceous or early Tertiary and the lake deposits are thought to be Miocene, the ores are probably early Tertiary.

Thus, dating the ores somewhere during that period when the great heat of the intruding granite magma was being slowly dissipated through the surrounding rocks, it seems very reasonable to suggest a relation between the two.

PLACERS.

The principal placers have been found along the Similkameen river about half way between Oroville and Nighthawk where somewhat more than a half million dollars is said to have been extracted within a short time after the discovery. Recently a river bed drying device has been installed, the object being to explore the present channel. Other placer operations are being undertaken on the river but with what success is unknown to the writer.

The gold which varies in size from coarse flakes to nuggets, occurs in the river bars and lower terraces. This part of the river valley is largely the product of post-glacial erosion, hence the placers are very young and quite possibly have been secondarily concentrated from vein material ground up by the ice sheet.

GROUND WATER LEVEL AND OXIDATION.

Perhaps the most striking feature in the ore deposits of the boundary country is the shallow zone of oxidation. In many instances this may be accounted for by the shallow depth of the water table. Usually, however, the water table is a considerable distance below the lower limit of oxidized ore. Thus in the Copper World Extension, primarily pyrite and chalcopyrite are encountered within a few feet of the surface, while water does not rise in the shaft above the 200-foot level. The Kelsey group also illustrates this point but here the water level is only 20 to 50 feet below the lower limits of predominant oxidation. Many other instances could be cited which illustrate the same general relation, namely, that the water level is lower than the present lower limit of oxidation.

This relation is probably to be explained by recourse to the influences of glaciation on the country. The ice not only cut off much of the oxidized zone in many places, but left a mantle of drift which serves to shed water that would otherwise enter the veins.

CONCLUSIONS.

Concisely stated, the conclusions deduced from the reconnaissance in the Oroville-Nighthawk area are as follows:

(1) Copper deposits occur both as veins and as disseminations. The former are definitely known, but the quantity of ore available is yet to be determined. The latter are in vast bodies but it is yet to be proven that the copper content is sufficient to justify working under present conditions.

(2) Gold production will probably be much lower, proportionately to silver and copper, in the future than in the past.

(3) The proportionate production of silver in the future will show a marked increase.

(4) The ores are probably genetically related to a great batholith of soda-rich granite.

(5) The deposits are thought to be of late Cretaceous or early Tertiary age.

(6) In few districts is the injunction to follow the ore more pertinent than here.

MINERALS OF THE DISTRICT.

The minerals recorded in a report of reconnaissance studies must in the nature of the case be incomplete, but for purposes of reference those that were noted are arranged in alphabetical order and their mode of occurrence briefly stated.

Argentite. Silver glance occurs in several of the silver-bearing deposits around Golden and Nighthawk but is never the chief ore of silver.

Arsenopyrite. This sulpharsenide of iron is not abundant in the area, being noted in but three places. It was intergrown in each case with vein quartz.

Auzurite. This copper carbonate is limited to the upper few feet of the copper deposits and even here is not conspicuous.

Bornite. Bornite occurs in many places as an alteration product intermixed with chalcopyrite and as thin films on adjacent material.

Calcite. The carbonate of lime frequently occurs as part of the gangue.

Cerargyrite. Hornsilver occurs near the surface in many of the silver-bearing veins but in no place constitutes a very appreciable part of the ore.

Chalcopyrite. This mineral is widely distributed in the area and is the chief ore of copper. It occurs in veins intimately intergrown with pyrite and as disseminations in the Paleozoic rocks.

Cuprite. Copper oxide is remarkably rare in the surface exposure of the copper deposits, the alteration having been almost completely to malachite.

Galena. Lead sulphide is widely distributed in the vein deposits. Silver is associated with it in several places and in one of the veins (Hiawatha) it is thought to carry much of the gold.

Gold. Gold is widely distributed in the area. It occurs free in placers and the upper portions of the quartz veins, and included in pyrite, chalcopyrite, galena, and sphalerite in the unaltered parts of the deposits.

Limonite. The hydrated oxide of iron occurs as a heavy stain on the gossans of the veins and on surface exposures of many of the rocks of the area, especially the basic lavas and tuffs.

Malachite. The green copper carbonate is always conspicuous in the outcrops of the copper-bearing deposits. It is generally confined to a few feet near the surface.

Molybdenite. Thin, graphite-like scales of the sulphide of molybdenum occur along many of the gouge seams accompanying the veins in the northeast part of the area.

Proustite. Light rubysilver is an important ore from the central and northwest part of the district. It usually occurs as stains and crusts but occasionally as small, hexagonal crystals in firm quartz.

Pyrargyrite. Dark rubysilver has a distribution similar to proustite and with it constitutes the chief ore of silver.

Pyrite. Pyrite occurs in all the deposits of the area.

Pyrolusite. This oxide of manganese was noted in several deposits both as druses and dendrites.

Pyrrhotite. Appears quite commonly in the quartzitic schists traversed by the Palmer mountain tunnel but was not noted in any of the veins.

Quartz. Quartz is the chief gangue mineral in the area.

Silver. Specimens of native silver have been encountered near the surface in several of the properties but does not constitute an ore of silver.

Sphalerite. Zinc blende is widely distributed in the veins. It occurs as fine-grained masses in the quartz but is never in commercial quantities.

Stephanite. Is one of the important silver ores especially in the Hornsilver mine. It is usually disseminated in irregular areas in the gangue but occasionally occurs as short prismatic crystals.

Stibnite. Antimony sulphide occurs in small lenses and bunches in the metamorphic rocks southeast of Loomis. Little of it was seen in place.

CHAPTER IV.

DETAILED DESCRIPTION OF MINES AND PRINCIPAL PROSPECTS.

In the descriptions which follow the properties will be divided into groups according to their location. Thus the claims situated near Oroville, Nighthawk, Wannacut Lake, and on Palmer mountain will be considered in turn. It is perhaps unnecessary to state that not all of the claims of the area were visited and it is likely true that some which were not visited are of more merit than some of those which were. It is thought, however, that the following descriptions in that they are to a large measure inclusive, will be of value in giving the report tangible form.

KELSEY GROUP.

The Kelsey group consists of fifteen claims which are situated about four miles north of Oroville and immediately west of Osoyoos lake. The property is owned by the Detroit-Oroville Exploration company with headquarters in Detroit, Michigan. Mr. N. B. Kelsey, of Oroville, Washington, is local agent for the company.

Development consists of several small open cuts and shafts in addition to six diamond drill holes, each of which reaches a depth of about 100 feet. No ore has been shipped from the property.

The country rock, as exposed on these claims, is predominantly greenstone, although large amounts of clay slate and quartzite are present. The greenstones seem to be interbedded with the sedimentary members, although it is possible that more careful study may show some of them to be intrusives. In the hand specimen they are usually green or greenish gray and present a granular to porphyritic texture with the grains rather ill-defined. Hornblende, feldspar, and quartz can be distinguished, and little veinlets of quartz usually less than a quarter of an inch wide occupy joint and fracture cacks. Chalcopyrite, commonly altered on its surface to a blue, black or green sheen, and pyrite occur as disseminations both along the quartz stringers and out into the rock mass. The specimens studied were so extensively altered that accurate classification was not possible. From such determinations as were made, however, it appears that the rock is a basic andesite, consisting of oligoclase, andesine and a few labradorite feldspars, biotite, titanite, zircon, apatite and magnetite. Secondary epidote is nearly always present in conspicuous amounts, while chlorite, kaolin and a little sericite are variously found. Pyrite or chalcopyrite, and usually both, were present in all the slides studied.

Mineralization has affected all varieties of the country rock, copper in the form of chalcopyrite occurring as disseminations and as films along fracture lines and bedding- and joint-planes. In places, non-persistent quartz veins carrying chalcopyrite and pyrite occur but strong fissure veins are not found. A remarkable feature of the deposits is the very shallow depth of oxidation. Primary minerals usually appear by knocking small chips from the surface, even where copper stains are most extensive. This clearly indicates that secondary concentration on a large scale cannot be expected. The company have had a great many assays made on various parts of the property and an average of eighteen of these which were selected at random from a number of assays furnished by Mr. Kelsey gave 2.62 per cent. in copper, 0.6 in silver and 0.04 ounces in gold.

In conclusion it appears that this group of claims contains widely disseminated copper, but whether the percentage of copper on a large tonnage basis is high enough to constitute an ore, has not been proven.

The deposits, while similar to the great disseminated deposits of the southwest, must be distinguished from them by one very important difference. In the southwest oxidation is extensive and the workable ore lies below this zone and is due to concentration from it, while here no such general zone of enrichment is to be expected. Chalcopyrite is the chief mineral of the deposit, even within a few feet of the surface.

OKANOGAN FREE GOLD MINE.

The Okanogan Free Gold mine lies on the north bank of the Similkameen river, about three miles above Oroville. Considerable work was done on the property several years ago and shipments of ore were made; but due to the high cost of mining which prevailed at that time, the mine was closed as soon as the richer oxidized ore had been worked out.

Development consists of several tunnels and open cuts. The lower tunnel was entered for a distance of 175 feet; otherwise observations are from the surface. This tunnel runs east through a finely laminated clay schist which is badly disintegrated and cut by numerous north-south stringers of quartz. At 175 feet from the portal the tunnel intersects a vein of milk-white quartz which is two to three feet wide. The vein, which strikes north 18 degrees west and dips steeply south of west, although apparently not mineralized at this level, has been stopped near the surface. Here it is from 6 feet to 25 feet wide and consists of blue and white quartz much fractured and including fragments of schist. Cubical iron pyrites are distributed through the gangue and out into the wall rock. Near the surface iron oxides are extensive and in places the quartz has a honeycomb texture due to the removal of pyrite.

GOLDEN CHARIOT.

The Golden Chariot claim is situated about five miles north of Oroville. Development consists of an incline 220 feet on the vein from which drifts extend out along the lode. Three cars of ore shipped from the property afforded an average return of about $26 per ton. Although the ore is mined for gold, yet some copper in the form of chalcopyrite is present.

The vein, which averages about two and one-half feet in width, strikes 15 degrees east of north and dips westward at angles varying from 40 degrees at the surface to eighteen or twenty degrees at a depth of 50 feet. The fissure is of about constant width and within are essentially equal proportions of vein matter and gouge. The gouge shows excellent cleavage inclined about 45 degrees to the walls. In tracing the cleavage planes they are seen to incline toward the surface as the hanging wall is approached (Fig. 2), thus indicating that the hanging wall has moved up relative to the foot wall. The vein therefore occurs along the plane of a thrust fault which, however, is thought to have only a small throw.

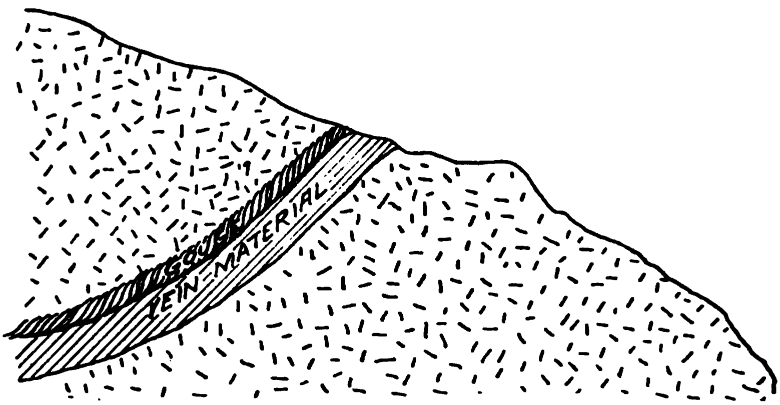

FIG. 2.—Golden Chariot vein which occurs along a thrust fault as shown by direction of cleavage in gouge near hanging-wall.

The ore is a bluish white to milky quartz with chalcopyrite as the chief metallic mineral. Pyrite is also present and occasional black metallic ribbons occur. In places the mineralization is confined to one side or the other of the lode and in others it is evenly distributed throughout, while yet again the quartz is entirely barren. Where mineralization is present it is in blotches distributed more or less parallel to the margins of the vein. Films of molybdenite are found, especially along the contact with the walls.

OHIO CLAIM.

The Ohio claim lies immediately south of the international boundary and a short distance west of Osoyoos lake. It is held for copper which occurs as disseminations in greenstone. The minerals noted were chalcopyrite, malachite, azurite, pyrite and chrysocolla. In no place is mineralization intense.

FORTY-NINTH PARALLEL MINING CO.'S PROPERTY.

This property consists of five claims situated near the Ohio claim. The vein, which is enclosed in the metamorphic rocks, strikes east-west and dips 36 degrees south. It does not appear strong at the surface, but below attains a width of about five and one-half feet. The gangue is a dense bluish white quartz enclosing chalcopyrite and pyrite, usually altered to carbonate and oxide forms. The ore is said to carry from $14 to $58 a ton, the ratio of copper to gold being about six to one with copper at thirteen cents.

NIGHTHAWK GROUP.

The Nighthawk Mine is situated on the east wall of Similkameen valley a few hundred yards south of the postoffice at Nighthawk. The company have 65 unpatented claims located in section 13, township 40 north, range 25 east, and section 18, township 40 north, range 26 east. Development consists of a main tunnel 1,770 feet to the face, at the date of examination,

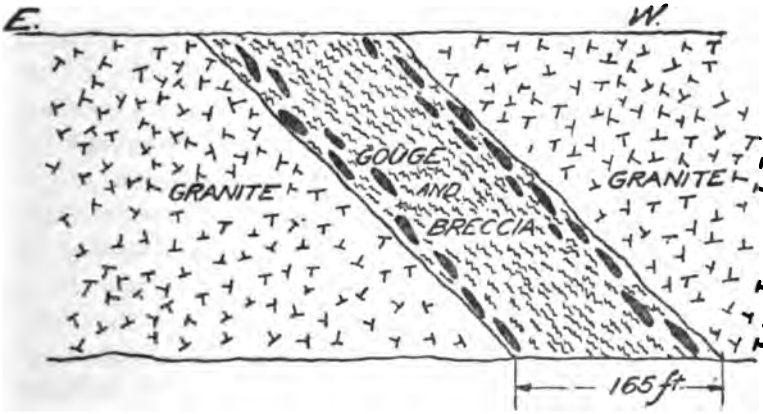

FIG. 5.—Showing the occurrence of ore along the margains of a brecciated sone in the Nighthawk Mine.

and several minor underground workings. A 20-stamp mill used for making concentrates is located near the portal of the main tunnel. Electric power for running the compressor and mill is furnished by the Similkameen Power Company.

The ore is enclosed in granite. That part being mined occurs as irregular bodies along the margins of a brecciated zone which is cut about 1,000 feet from the portal on the tunnel level and at this place is a little over 100 feet wide (Fig. 5). The hanging wall side of the zone is clearly defined while that opposite is more gradational. The principal ore has been taken from near the hanging wall and comes from small bodies of quartz which vary markedly in extent of mineral content from place to place. The quartz is friable and often minutely mixed with gouge material. In places it is distinctly fractured, thereby showing post-mineral movement. The mine is worked for lead and silver which are intimately associated with considerable amounts of iron pyrite.

FAVORITE MINING CO.'S PROPERTY.

This property is situated a short distance south of the Nighthawk mine on the east side of the valley. At the date of the examination, a tunnel running a little south of east had reached a point 850 feet from the portal but had not yet reached the vein for which it was being driven. The country rock is a light gray granite more or less mottled by hornblende crystals. Euhedral titanite crystals are present in the rock and may be recognized by their reddish brown color.

LITTLE CHOPAKA GROUP.

This group consists of eleven unpatented claims formerly known as the Six Eagles group. They lie on the west side of Similkameen valley about one mile south of Nighthawk. The principal development consists of a 200-foot shaft on the ledge and a tunnel 2,000 feet long on a level 500 feet below. The tunnel should have cut the vein at 1,500 to 1,600 feet, but instead a seam of gouge was encountered.

The vein is along a fault which runs north 2 degrees east and dips 45 degrees northwest. The hanging wall is well defined and shows distinct vertical groovings while the foot wall is gradational. Along the foot wall and also within the vein there is considerable gouge. Where seen the vein is from one to three feet wide and varies in position from the middle of the gouge material to the hanging wall. The gangue is a milky colored quartz carrying pyrite, chalcopyrite, sphalerite, galena, rarely sericite and occasionally a black nonmetallic substance in the form of small specks, which is possibly gouge material. The property is held for gold, silver and lead, said to total about $5 per ton. The country rock is granite similar to that above described.

SUMMIT CLAIM.

Summit claim joins the Little Chopaka group on the south and is located on the same ledge. The vein, as exposed in an incline shaft some 70 feet deep, is about three and one-half feet wide and carries pyrite, galena, some chalcopyrite and a little sphalerite, occasionally molybdenite and rarely sericite irregularly scattered in a gangue of firm, milk colored quartz.

The enclosing rock, which is similar to that on the Little Chopaka property, is a light gray granite with conspicuous crystals of hornblende, frequently irregular in outline and in striking contrast to the light colored feldspars which are the chief constituents. Some of the feldspars are distinctly striated and lath-shaped with glassy luster. Quartz grains are present. Under the microscope the feldspars are seen to be microline and albite, while orthoclase is very subordinate in amount. Quartz represents about ten per cent. of the rock, and titanite about one per cent. Secondary epidote, sericite and calcite are extensively developed, together with some hornblende and chlorite. In passing it may be noted that the specimen from this property is much more basic than the average of the batholithic mass of which it is a part.

NUMBER ONE GROUP.

Number One group is situated on the south face of Little Chopaka mountain about one and one-half miles south of Nighthawk and west of the Little Chopaka group. Development consists of a tunnel 200 feet long and several shafts, the deepest of which is 60 feet and connects with the tunnel level. The lode is from 3 feet to 12 feet wide and occurs along a fault plane which extends north-south and dips 31 degrees west. The vein can be followed on the surface for some 4,000 feet. Silver and lead, occurring in a friable quartz gangue, are the chief metals although a little gold and copper are usually present. Assays from the property show wide variations, but it is probable that the average will be found to be somewhat less than $10 per ton. The quartz is considerably fractured and in the tunnel level is so leached that galena is the only primary mineral remaining in conspicuous amounts. From the degree of weathering and the silver near the surface, it is thought probable that silver will be found to increase somewhat in amount down to the ground water level.

The hanging wall of the lode is a decomposed conglomerate in its lower part with slate above while the foot wall is a fresh granite face with texture and composition characteristic of the interior of the granite mass and showing none of the peculiarities expected along a marginal contact. This, together with the distribution of the two formations, clearly indicates a fault with downthrow on the west.

CALIFORNIA CLAIM.

This property is situated near the south base of Little Chopaka mountain. The vein, which is exposed in a tunnel 150 feet long, is from 6 to 12 feet wide and composed of coarse quartz with occasional vug-like cavities. The metallic content is distributed in patches through the gangue, the patches being arranged with a certain parallelism which gives the face a roughly banded appearance. Chalcopyrite, bornite, pyrite, sphalerite, and galena are the principal primary minerals, while secondary iron and copper stains are conspicuous locally. The wall rock is granite and a part of the same batholith which occurs to the north on the Little Chopaka and other properties.

PEERLESS GROUP.

The Peerless group consists of twenty claims situated in the Paleozoic area on the south face of Little Chopaka mountain. Several tunnels and shafts have been opened on the property, the principal one of which is a tunnel 400 feet long starting from near the level of Similkameen valley and extending north. Here the country rock is quartzitic slate and black metamorphosed shale together with some greenstone. No true ledge has been encountered but in places the rock passed through carries much magnetite, pyrite, and some chalcopyrite. Small garnet crystals were noted in two places.

CAABA LEAD.

In the north half of section 23, township 40 north, range 25 east, there are several prospects along a vein which strikes north 2 degrees west and dips 45 degrees southwest. The vein, which crosses the contact between the granite and metamorphic formations, is from 6 to 12 feet wide and shows a coarsely banded structure almost resembling bedding. The gangue is quartz, which is loose and friable and presents many crystal lined cavities irregularly distributed from wall to wall. Galena and pyrite occur along zones parallel to the banding of the quartz. Assays show silver chiefly, with usually about 50 cents in gold, the total being between $2 and $4 per ton.

PRIZE GROUP.

Prize group, consisting of twelve unpatented claims, is situated on the east side of the valley about three-fourths of the way from Nighthawk to Palmer lake. A small mill with a capacity of one ton per hour is used for making concentrates. The workings, consisting of two tunnels, are on the face of the mountain at an elevation of 3,200 feet. The vein is enclosed in greenstone and schist and strikes almost east-west, dipping south. The quartz is in large part intermixed with country rock, both enclosing fragments of it and extending into it as irregular stringers. Galena, pyrite and chalcopyrite, together with malachite, azurite, and iron oxides are irregularly scattered through about fifteen inches of quartz. The metals sought are silver, lead and gold.

RUBY MINE.

Ruby mine is situated on the east face of Mount Chopaka near the level of Similkameen valley and about one and one-half miles north of the north end of Palmer lake. Some 6,000 feet of development work has been done on the property, 1,300 feet being in tunnels, which give a depth on the lode of 480 feet, and the remainder in drifts, raises and crosscuts. Two leads have been encountered, only one of which is of commercial 1,300 feet being in tunnels which give a depth on the lode of importance. This occurs along a fault plane which strikes north-south and dips 45 degrees west. Heavy black gouge, largely composed of powdered and secondary hornblende, occurs along the fault plane and is usually mixed with the ore. The ore shows a tendency to follow the hanging wall, but exceptions are numerous. Although the fissure is very irregular in width, varying from three or four to twenty feet, yet the ratio of vein material to gouge varies even more markedly from place to place. On the whole, gouge predominates. The vein matter occurs as lenses, stringers and as cement in brecciated material and varies from one-half inch to twelve or more feet in thickness, averaging about fifteen inches. It is frequently banded and includes much fragmental material.

The ore is milky white, friable quartz containing about five per cent. of lime, and carries pyrite, chalcopyrite, arsenopyrite, galena, sphalerite, proustite, pyrargyrite, some argentite and a little free gold, besides the alteration products—malachite, azurite and limonite. In detail, minerals are usually irregularly scattered through the quartz, although in broad outline they are zonally arranged. Supt. Monroe Harmon estimated that 35 to 40 thousand tons of ore of an average value of $10 per ton, is blocked out above the tunnel level and awaiting the installation of an electro-metal plant.

The enclosing rock is gabbro, varying in places to hornblende diorite, and in others less common, to dunite. It is very rich in hornblende, often running as high as 73 per cent. in that mineral and seldom falling below 40 per cent. Apatite is conspicuous, sometimes representing 5 per cent. of the rock. A very little quartz is usually found and near the lode assays show traces of the vein metals. The exact relations of this basic rock to the granite which occurs on all sides of it, was not definitely determined, but it may be a differentation from that mass.

MOUNTAIN SHEEP PROPERTY.

This property is situated about three-quarters of a mile north of the Ruby and on the same fault. Extensive development work has been done in tunneling and otherwise exploring the vein. The deposit and its occurrence is similar to that at the Ruby mine. Some few cars of ore have been shipped.

GOLDEN ZONE MINE.

Golden Zone property, consisting of five patented claims, is situated at the base of Mount Chopaka about two miles south of the international boundary. The main lode, which strikes 20 degrees east of north and dips 40 degrees northwest, has been developed by some 5,000 feet of tunnel and drifts giving a depth on the vein of over 500 feet. A stamp mill for preparing concentrates is situated on the property and was in operation for about four years, when, due to litigation, it was closed. The property is held for gold, although some silver is present. In the upper levels free gold was found, but below the metal is intimately associated with iron sulphide, while the silver present seems to be as argentiferous galena. Chalcopyrite and occasionally sphalerite and arsenopyrite were noted on the dump. The country rock is granite, although the metamorphic rocks outcrop but a short distance to the south.

RICH BAR PROPERTY.

The Rich Bar Mining Company hold eleven claims on Similkameen river about five miles east of Nighthawk. The group receives its name from the placer which was worked as far back as 1859. Quartz lodes were recognized at that time but due to withdrawal from mineral entry shortly thereafter, were not definitely located until 1901, when Mr. Charles T. Peterson staked out the several claims. Development consists of two shafts, the larger of which attains a depth of 150 feet, or 60 feet below the bed of the river, with drifts from the 50 and 150 foot levels. On the 50 foot level the vein tends to be in stringers, but below is better defined, and in the face exposed at the date of the examination was about 6 feet wide. At this place the vein strikes north 40 degrees west and dips 35 to 40 degrees northeast. The lode material, which is enclosed in a quartzitic slate of the Paleozoic series, is bluish white and varies greatly in mineral content from place to place. Where mineralized it carries chalcopyrite, sphalerite, pyrite, stephanite, galena and argentite, named in order of decreasing importance. Present developments suggest that the richer ore occurs in the central part of the vein. Assays differ greatly from place to place, varying between traces and $40 per ton.

SIMILKAMEEN PLACERS.

Placers were worked on Similkameen river as early as 1859, and in the few years following some $500,000 is said to have been shipped from the section of the river between Oroville and Nighthawk. During recent years placer mining has been pursued by a few individuals on this part of the river almost continually, but with only moderate success. During the season of 1909 a Gilman riverbed dryer was installed, the object being to work the bed of the river. At the time of investigation the installation was incomplete, and although operated since the results are unknown to the writer.

The gold occurs as flake gold, shot gold and nuggets, and is found in the river bars and lower terraces.

KIMBERLY MINE.

Kimberly mine is situated one-half mile south of the old postoffice at Golden. An incline shaft on the vein is 140 feet deep with drifts on the 60, 80 and 100 foot levels. The lode occurs along the contact (possibly a fault) between a highly altered igneous rock of intermediate composition on the foot wall and clay slate on the hanging wall. It strikes north 46 degrees west and dips 52 degrees southwest. Within the deposit the ore occurs in lenses which vary in dimensions up to 40 or 50 feet in length by one to five feet in width, and always have a flatter dip than the vein. Thus the lower end of any lens overlaps the upper end of the next lower lens on the hanging wall side (Fig. 4). The gangue is massive bluish white quartz, rich in galena with some pyrite and chalcopyrite. The property is worked for lead, gold, and silver which according to Supt. S. A. DeMerchant, occur in the better ore in about the following amounts: lead 10 to 20 per cent; gold $6 to $15; silver 60 to 70 ounces.

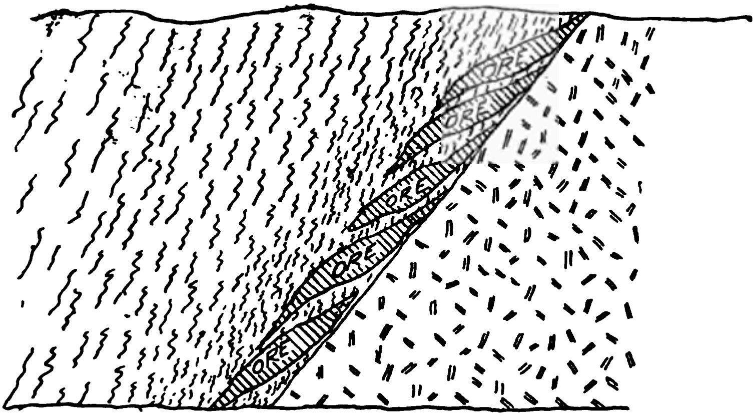

FIG. 4.—Section of Kimberly lode, showing distribution of ore in lenses.

TRIUNE MINE.

The Triune mine is situated one-half mile west of the old post-office at Golden and about the same distance northwest of the Kimberly. There are three claims in the group but most of the development has been done on one of them. There are several open cuts and small shafts but the principal development is a shaft 140 feet deep and a tunnel on a lower level, which, together with drifts from it, comprises somewhat over 2,000 linear feet.

All of the ore mined has been treated in a small stamp mill. The mine was formerly owned by Mr. Dell Hart of Wehesville, who operated it successfully for some years. Since its transfer to the Triune Power and Reduction Company of Boston, Mass., development has been carried on, but no ore milled.

The vein strikes north-south and dips 20 to 40 degrees east, the variation being from place to place along both the strike and dip. In harmony with this is a pronounced irregularity in width, varying from small stringers up to six feet. The gangue is milky white quartz carrying irregularly arranged, but usually bunched, galena and pyrite with the gold largely accompanying the galena. An average mill run, from stopes within 50 feet of the surface, gave returns of a little over $25 per ton. A stope of this grade of ore, and it represents essentially all the stoping on the property, is 365 feet long by 50 feet deep and averages about two feet in width. It opens to the surface. In a tunnel driven to cut the lode on a lower level four veins were encountered, all of which strike west of north and dip west. They vary greatly in width along the strike, averaging perhaps less than 18 inches and afford assays ranging from traces up to $15 in sections across the vein and up to $40 in roughly handpicked samples.

The wall rock is clayey quartzite in the upper part and porphyritic granite below about 75 feet. The latter is coarse grained, consisting of quartz and pink orthoclase in almost equal proportions and together usually constituting about 90 per cent. of the rock. Hornblende varies in amount, and in places largely supplants quartz. Occasional feldspar crystals are two inches long and stand out boldly in a granitoid matrix, hence requiring the name porphyritic granite. The rock is highly altered, much epidote, sericite, kaolin and secondary pyrite being present. The ores are thought to be genetically related to porphyritic granite.

The Spokane claim is on the same general lode as the Triune and lies just south of it. Since the relations in it are very similar to those in the Triune it will not be described separately.

HIAWATHA LODE.

The Hiawatha vein lies north of the Triune and is very similar to it in general characteristics although in detail somewhat different. An incline 80 feet long follows down the dip which is about 10 degrees west at the surface and increases to 45 degrees at the bottom. The vein outcrops for a few hundred feet south from the shaft, but to the north it can be traced for over 2,500 feet by a well defined gossan of white quartz, which in places is heavily iron stained. It varies from one to twelve feet in width, averaging 3 to 4 feet. In places the lode breaks into stringers and in others is offset by small faults, but as a whole is strong and continuous. The ore is a friable white quartz carrying sphalerite, galena, pyrite, and chalcopyrited distributed in bunches through it. Mr. Dell Hart, who owns the property, has made careful assays of the various minerals separately, in order to determine the one with which the gold is associated, and found that galena carries by far the greatest quantities, while chalcopyrite and pyrite follow in the order named. Mr. T. F. Philbrook has sampled the property and reports $26 in gold with about an ounce in silver, as the average of 22 assays.

The wall rock is clayey quartzite in the parts now exposed, although it is very possible that the granite rock which underlies the Triune will be encountered at no very great depth.

TRINITY GROUP.

Trinity Gold and Silver Mining Company have four claims situated in the northeast quarter of section 28, township 40 north, range 26 east. Development is largely confined to the southeast claim, where there is a 40-foot shaft and a tunnel 200 feet long. Near the entrance the tunnel is in slate, while farther in a bed of black calcareous shale about fifty feet thick is encountered. Within the latter are occasionally very irregular lenses of quartz which are somewhat mineralized. Two or more quartz ledges which have not been developed outcrop on the north claims.

HORN SILVER GROUP.

The Horn Silver group consists of five claims situated in the south half of section 21, township 40 north, range 26 east. The property is developed by 750 feet of tunnel, an upraise of 100 feet and a shaft 100 feet deep. Three veins are recognized but most of the development has been on one of them, which strikes north 53 degrees east, and dips about 40 degrees northwest. The vein is very irregular in strike, dip and thickness, the latter varying from four inches to four feet, averaging about 18 inches. The country rock is in part a metamorphosed shale and in part a highly altered granite which shows the microcline, microperthite and titanite which characterize the great granite area to the north. It is probable that here is a small area where erosion has gone just far enough to partially uncover an underlying batholith which now appears at the surface in broad areas to the north.

The ore is white to bluish white quartz which as a rule is well mineralized, carrying stephanite, cerargyrite, a little proustite, galena, sphalerite, pyrite and chalcopyrite. The metallic minerals are distributed irregularly through the vein. In rare places they are along fracture lines, but more frequently are so intergrown with the quartz as to be unmistakably of contemporaneous origin.

Several carloads of ore have been shipped from the property, the two during the summer of 1909 averaging $62 per ton. The return was largely from silver with about $2.50 in copper and gold.

MAQUAE GROUP.

The Maquae group includes twelve claims, no one of which is sufficiently developed to afford satisfactory opportunity for observations. Three or four different veins are exposed on the property and in each the gangue is quartz with small amounts of calcite. The veins are held for gold and silver with which pyrite, galena, sphalerite and chalcopyrite are associated. A few stains of manganese were noted on the gossan at different places.

BELLEVUE GROUP.

This group consists of five claims situated in the northwest quarter of section 4, township 39 north, range 26 east. The principal lode, which strikes north 29 degrees east and dips 45 to 66 degrees southeast, is developed by a small shaft and several open cuts. The vein is enclosed in clay slates in the upper part and probably in limestone below, as indicated by the dip of a massive limestone member which outcrops about 600 feet east. The vein varies from ten inches to three feet in width and averages about 15 inches. It is made up of heavy, coarse textured quartz carrying arsenopyrite, pyrite, chalcopyrite, pyrargyrite, stephanite, a little native silver, free gold, and possibly a gold-silver telluride. A test shipment of 1,000 pounds gave returns of about $75 per ton in gold and silver with gold representing a little over one-half the total.

BULLFROG GROUP.

The Bullfrog group comprises 18 claims in the southwest part of section 33, township 40 north, range 26 east. There are two shafts, one 140 feet deep and the other 160 feet deep, in addition to a tunnel. The two shafts are connected by a crosscut, while other explorations have been made from each. The lower workings are said to crosscut three ledges, two of which show on the surface. The shafts were flooded at the date of the examination, but from the dump the wall rock is thought to be largely quartzite and sericitic schist. The ore is coarse textured quartz with pyrite and small black specks of some metallic sulphide rather sparsely scattered through it.

PALMER LAKE GROUP.

This group is situated well up on the valley side northeast of Palmer lake, and consists of five claims. The vein where seen is from two to three and one-half feet in thickness, strikes north 65 degrees west and dips 30 degrees northwest. The gangue is a massive, white quartz carrying small amounts of pyrite, chalcopyrite and bornite. The property is held for gold.

IVANHOE MINE.

In the early days of mining in the district considerable ore was shipped from the four claims which comprise the Ivanhoe group. The property is situated in the southwest quarter of section 16, township 39 north, range 26 east. The vein, which is enclosed in calcareous slate, is a fine-grained, greatly fractured quartz heavily iron-stained at the surface. Fresh ore as seen on the dump has a gangue of white quartz enclosing pyrite and some dark mineral or minerals which occur in streaks and ill-defined blotches. Silver is the chief precious metal, although some gold is present. The mine has been idle for about ten years, but during its period of operation ore was hauled to Wilbur and Coulee City and from there shipped to the smelter.

RAINBOW MINE.

The Rainbow mine, situated in the northeast quarter of section 22, township 39 north, range 26 east, was operated for some time during the early mining excitement and the ore treated in a mill located nearby. The vein, which is enclosed in metamorphosed limestone, schist and quartzite, is developed by three principal tunnels. It is very irregular in strike, dip and especially in thickness, occurring in lenses which thicken and pinch at short intervals. The quartz carries gold and silver accompanied by pyrite, arsenopyrite, chalcopyrite, and galena. Secondary iron and copper minerals are very limited.

BUCKEYE CLAIM.

This is one of eleven claims owned by Mr. A. M. Wehe, of Wehesville. A small vein averaging about one foot in width is opened on the property. Metallic minerals present include pyrite, chalcopyrite, galena and occasionally stephanite. Gold is said to predominate over silver. Present development is inadequate to determine the extent of the lode. The country rock is quartzite and siliceous schist.

COPPER WORLD EXTENSION.

Copper World Extension, also known as the Iron Mask property, is situated just west of the summit on the central part of

Palmer mountain. The claim joins the Copper World on the east and from that derives its name. The country rock is principally clay slate, although some schist and quartzite fragments appear on the dump. Development consists of a vertical shaft 300 feet deep, which is sunk in the foot wall of the vein and connected with it by crosscuts on various levels. Most of the drifting has been done on the 200 foot level. The ore body does not appear at the surface, but 100 feet below attains a width of four and one-half feet. Where crosscut at 200 feet, it is reported to be seventeen feet wide, while on the 300 foot level it is said to split into numerous small stringers. The deposit consists almost entirely of pyrite and chalcopyrite, so proportioned that the ore runs about four per cent. in copper. About one ounce of silver and from fifty cents to one dollar in gold are usually present.

The ore body strikes north 85 degrees west and dips 40 degrees southwest. Although tabular in general outline, it is not sharply defined. In places pockets of ore are found within the walls a few feet from the vein and isolated cubes of pyrite are rather generally distributed in the adjoining rock. Along the hanging wall the schist has been ground into gouge which is a few inches wide and probably indicates a line of pre-mineral movement followed by the ore solutions. Within the ore fragments of schists always heavily mineralized, are frequently met, further suggesting replacement along a zone of movement. Between the one hundred and three hundred foot levels a body of ore about two hundred feet long and of varying width has been blocked out.

Although considerable tonnage was extracted during several years, the property has not produced recently, due to lack of transportation facilities. The owners are now considering the feasibility of carrying the ore by areal tram from the mine down into the valley near the south end of Palmer lake, a distance of about two miles, from which point a haul of seven miles will place it aboard the cars at Nighthawk.

COPPER WORLD.

The Copper World property joins the Copper World Extension on the west, and is located on the same lode. The vein here has a surface exposure which, although not pronounced, can be traced for some distance. An incline shaft follows the dip of the ore body for 135 feet. At the time of the investigation the shaft contained water and only inferences from material found on the dump were possible. The country rock is schist and slate, much of which is found intimately mixed with the ore. Pyrite and chalcopyrite are the chief metallic minerals.

SECOND PRIZE GROUP.

The Second Prize group consists of nine unpatented claims owned by Mr. Charles Gerhart of Loomis, Washington. Development consists of small pits and tunnels located on various claims. The Second Prize claim is developed by two tunnels, one about seventy and the other one hundred and twenty-five feet deep. The latter or lower tunnel shows a small seam six inches to three feet across but averaging probably about fifteen inches, which follows a fault line. In the upper tunnel a quartz vein three to four feet wide strikes north 54 degrees east and dips 60 degrees northwest. An eighty foot winze extends from the tunnel and is said to contain very good ore in ten inches next to the foot wall. The enclosing rocks are schists, black slates, and quartzites.

On the Columbia claim a shaft thirty-five feet deep follows a body of quartz which, although very good at the surface, pinches out at the bottom. The ore consists of gold-bearing pyrite with an almost equal amount of arsenopyrite. The strike, although not clearly defined, seems to be about north 15 degrees east with dip 60 degrees northwest.

There are various other tunnels and small shafts on the property but those enumerated seem to present the most encouraging prospects.

LEADVILLE GROUP.

The Leadville group of claims lie on the west face of Palmer mountain at an elevation of 2,500 to 3,000 feet. They are reached by wagon road, which extends from Loomis to the Copper World Extension and continues west to this group. Several minor openings have been made along various croppings on the property but the principal development consists of a tunnel about 300 feet long and a shaft some 70 feet deep. The vein, which strikes north 60 degrees east and stands almost vertical, is two to three feet wide and carries galena, iron pyrite and chalcopyrite in a massive, white quartz gangue. The property is held for gold. The outcrop of the vein is strong and can be traced for a considerable distance up over the mountain, but does not appear in the valley side to the west. The country rock consists of the various phases of the metamorphic series.

PINNACLE MINE.

This property was one of the claims early located in the district and perhaps has a greater production to its credit than any other. The amount of bullion taken from the mine varies greatly, according to the estimates of different individuals, but is considered by those now holding the property to be about $200,000. At present the tunnels are caved so that it is impossible to see the vein underground. In a bluff south of the main portal, however, is an old stope about five feet wide, from which the richest ore is said to have come. Another stope of high grade ore was found in the main tunnel at the junction of the Pinnacle vein with an east-west vein known as the Bunker Hill. At this point the quartz is from four to ten feet wide and average about $11 across the entire face, although extremely rich pockets and small seams are reported, the latter running parallel with the walls. The vein strikes north 60 degrees east and stands almost vertical.

The country rock is a highly altered igneous rock, probably diabase. In talus below the mine great quantities of black slates and some schists were noted. A gravity tram connects the mine with the base of the hill a short distance from a small stamp mill in which the ore was treated.

PALMER MOUNTAIN TUNNEL & POWER CO.'S PROPERTY.

This company holds an extensive group (about fifty) of unpatented claims. Extensive development consists chiefly of a double-track tunnel starting about a half mile north of Loomis and extending into the mountain a distance of about 4,800 feet. At various places in the tunnel drifts have been run to the east and west along quartz stringers or movement planes; in all totaling about 2,000 feet. In one place a quartz vein three feet wide is followed for a considerable distance, but is almost devoid of metallic content. Another stringer, ten inches wide, also developed to a considerable extent, gave an assay return from a sample taken by the writer of $1.80. These were the two best showings seen at the time of the investigation.

On the hill directly above, and about one-half mile northeast of the portal, is a shaft on the Black Bear claim. The shaft is down about 300 feet on a vein which strikes north 65 degrees west and dips 80 degrees northeast. At the surface, there is from fifteen inches to three feet of coarsely crystallized quartz, which in many places is stained by iron and manganese. It is said to have run about $24 per ton in gold, but pinched out on the 300-foot level. The main tunnel is well past the point where this vein should appear but it was not found. About a mile further up the hill from the Black Bear and in a general course with the main tunnel, is a quartz vein outcropping on the Grand Summit claim, which has produced some very good ore. At the time of the investigation, this outcrop was being explored by small tunnels in order to learn its characteristics, and hence the probability of finding it on the main tunnel level. Fourteen inches of quartz which appear in the floor of an upper prospect runs from $35 to $40 per ton in gold. The vein strikes north 55 degrees west and stands about vertical. Its position on the level of the main tunnel, if it should extend that deep, is several hundred feet beyond the present face.

There is one other claim in the group (Commanding) which affords some prospects. The vein here found strikes north 23 degrees west and dips to the east at a high angle. There is very little development work on this claim, but in one of the smaller pits extensively leached and copper stained material is exposed. It is from five or six feet wide, between poorly defined walls, although float can be traced for several thousand feet along the strike.

The company has extensive equipment. A power plant is situated in Toats Coulee, from which power for lighting and mining purposes is derived. A thoroughly equipped machine shop is situated near the portal and a one-hundred-stamp mill in which the stamps have not been installed, stands a short distance away.

ANTIMONY PROPERTY.

The Antimony property is situated in the northwest quarter of section 30, township 28 north, range 27 east, just beyond the southern limit of the map. Development consists of a tunnel 200 feet long. The country rock is slate and quartzitic shale. No true vein was seen in the tunnel, althought there are short, irregular drifts in two or three places from which ore has probably been removed. On the dump several pieces of beautiful stibnite were noted, but very little was seen in place.

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PUBLICATIONS

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Volume 2.—Annual Report for 1902. Part 1, The Building and Ornamental Stones of Washington, by S. Shedd; part 2, The Coal Deposits of Washington, by Henry Landes and C. A. Ruddy. Postage 20 cents. Address, State Librarian, Olympia, Washington.

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WASHINGTON GEOLOGICAL SURVEY

HENRY LANDES, State Geologist

BULLETIN No. 6

GEOLOGY AND ORE DEPOSITS

OF THE

BLEWETT MINING DISTRICT

By CHARLES E. WEAVER

1889

OLYMPIA, WASH.:
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LETTER OF TRANSMITTAL.

Governor M. E. Hay, Chairman, and Members of the Board of Geological Survey:

GENTLEMEN—I have the honor to submit herewith a report entitled "Geology and Ore Deposits of the Blewett Mining District," by Charles E. Weaver, with the recommendation that it be printed as Bulletin No. 6 of the Survey reports.

Very respectfully,

HENRY LANDES,
State Geologist.

University Station, Seattle, March 10, 1911.

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INTRODUCTION.

FIELD WORK AND ACKNOWLEDGMENTS.

This report includes a short history of the developme the mining industry at Blewett, the topography and phy raphy, a description of the geological formations, the geol history and structure, a description of the character an pearance of the ores, and a detailed description of the dif mining properties.

The geological field work, of which this paper repr the results, was carried on during the summer of 1910. Wor begun on June 13th, and continued until July 19th and d this time the areal geological mapping was completed an preliminary underground work begun. Later in the same during October, two weeks were spent in completing the de underground surveys and in studying the ore deposits. D the summer of 1908 six weeks were devoted to a study o district but not in connection with the State Geological S The results of that investigation have been freely used in nection with the data obtained during 1910. The winter m of 1910 and 1911 have been largely devoted to working u data collected and in preparing this report.

The topographic base map, upon which the areal geolog been represented, is a photographic enlargement of a smal tion of the Mount Stuart Quadrangle and is on a scale of inches to the mile. Because of this enlargement many represented topographic features may appear distorted. the most extensive mining developments in this district hav carried on in Culver gulch, a detailed topographic map on the scale of 200 feet to the inch and having an area of about one square mile, was constructed. Upon this map every important outcrop, including the veins, was mapped by a transit and stadia survey and tied to the United States mineral monument at the head of Culver gulch.

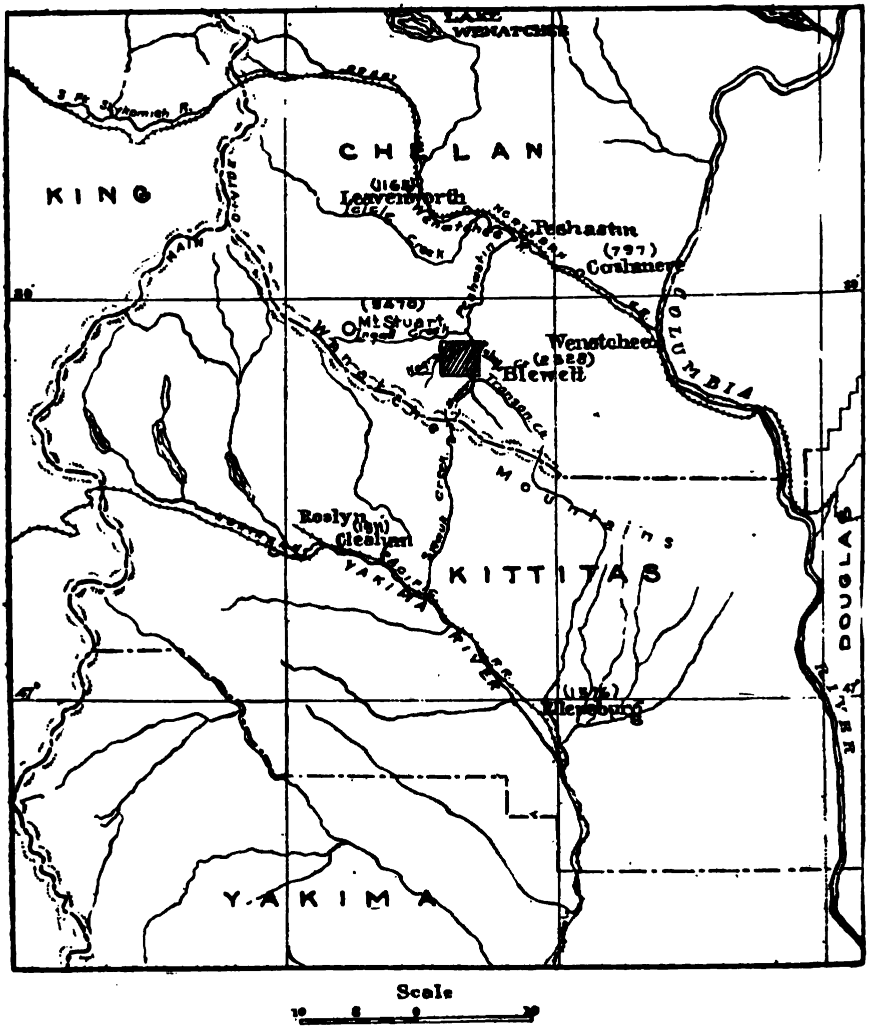
The writer was assisted in this work by Mr. Charles R. Fettke, who did a large part of the drafting and a part of the assaying. The chemical analyses were made by Mr. M. C. Taylor, of the department of chemistry at the University of Washington, and the majority of the assays were made by Professor C. R. Corey, of the School of Mines at the State University. Many of the chemical analyses included in this report have been taken from the Mount Stuart and Snoqualmie folios of the United States Geological Survey but due credit has been given in each case.

Throughout this work much assistance has been willingly rendered by the miners and citizens of Blewett. The larger number of the old mine workings were caved and impossible of entrance but several of the miners in this camp who had worked in them during the early days of mining identified many of the openings and with the writer explored them as far as possible. The writer wishes to thank all who have assisted in the carrying out of this work and especially Mr. Jack McCarty and Mr. John Olden, the latter having been one of the pioneers in the early seventies when the first quartz locations were being made. From both of these men much valuable information concerning the early history of the district was obtained. Many thanks are due Mr. Thomas A. Parish of Seattle, President of the Alta Vista Mining Company at Blewett, for the many courtesies extended, including the placing of his cabin at the disposal of the party throughout the entire field season.

LOCATION AND AREA OF THE DISTRICT.

The Blewett Mining District, which is sometimes known as the Peshastin Mining District, is located in the south central part of Chelan county, approximately in the center of the State of Washington. It lies west of Columbia river and east of the main divide of the Cascade mountains, in the upper part of Peshastin valley, at about latitude 47° and 25′ north and longitude 120° and 40′ west. The areal limits of this district are not very well defined but it may be said in general to comprise all of the mining claims situated on upper Peshastin creek down as far as the mouth of Ingalls creek, including its tributaries. The claims on Negro creek, however, are often referred to as a part of the Negro Creek Mining District. In this report an area of approximately nine square miles has been selected which includes all the more important mining claims, with the possible exception of two or three on the upper part of Negro creek.

About one-half mile to the east of the center of this areal map at a point where Culver gulch empties into Peshastin creek, is situated the town of Blewett, at an altitude of 2,328 feet, with a population at the present time of about forty people. This town is situated on the north side of the Wenatchee mountains, which form the water shed between the drainage basin of Wenatchee river on the north and Yakima river on the south. To the north the most important towns are Wenatchee, at the junction of the Wenatchee and Columbia rivers, Cashmere, Peshastin, and Leavenworth. These towns are all connected by the main transcontinental line of the Great Northern Railway, on the Seattle-Spokane division. To the south are the towns of Cle Elum and Ellensburg, which are connected by two transcontinental railroads, the Northern Pacific, and the Chicago, Milwaukee and Puget Sound. In the early days of mining, Blewett was



MAP OF EASTERN PORTION OF CASCADE MOUNTAINS BETWEEN THE WENATCHEE AND YAKIMA RIVERS.

▨ Area Representing Blewett Mining District Areal Geology Mapped connected with the outside world by road to Cle Elum, a distance of thirty-two miles. This road extends from Blewett southward up Peshastin creek for a distance of about nine miles, to the summit of the Wenatchee mountain ridge, the last mile of the nine having a 500-foot grade. South of this divide it passes down to the valley of Swauk creek. For the first two miles it has a 500-foot grade, and then extends down this same creek to a point about four miles below the town of Liberty and thence turns westward to Cle Elum. Later, in 1898, the wagon road to the north was completed through to the town of Peshastin, a distance of eighteen miles, and from there is connected by both wagon road and railway to Leavenworth and Wenatchee. The distance from Peshastin to Seattle along the line of the Great Northern Railway is one hundred and forty-six miles, and from Spokane is one hundred and ninety-three miles. Along the road from Peshastin to the mouth of Ingalls creek the grade is very moderate, averaging about forty-four feet per mile. From Ingalls creek southward to the town of Blewett it increases to 100 feet to the mile, but owing to the steep, canyon-like character of the valley above Ingalls creek, the grade becomes exceedingly irregular and in many places is much greater. Blewett is connected with Peshasin over this road by a tri-weekly stage and mail service and also with Seattle by long distance telephone connection by way of Cle Elum.

INDUSTRIES AND SETTLEMENTS.

The only industry of any importance within the Blewett district is mining. To the north of Blewett, in the lower portions of Peshastin valley, there are many small farms where alfalfa, apples and small fruits are raised. The extreme northern portion of Peshastin valley is a part of the famous Wenatchee apple orchard district. To the south, in the valley of the Swauk, wheat and other crops constitute the chief products. During the summer months large bands of sheep roam over the hills and mountain slopes and feed on the native grasses. In the town of Blewett there is one store, hotel, and postoffice. During the early days of mining Blewett was a thriving town with a population of several hundred people, but at the present time, due to the inactivity of mining, it has dwindled to a mere handful.

LITERATURE.

The literature bearing upon the geology and ore deposits of the Blewett Mining District and the surrounding country is not extensive, but a part of it represents the results of thorough detailed investigation by prominent geologists. The following list embraces the more important publications referring directly to the geology of this region. Many other references may be found in technical magazines and newspaper clippings which, while they refer to many phases of the history of mining of the region, are not deemed of sufficient geological interest to be included in the following list:

RUSSELL, ISRAEL C., A Geological Reconnoissance in Central Washington, Bulletin 108, U. S. Geological Survey, Washington, D. C., 1893.

This paper describes the scientific result of a general reconnoissance of the eastern portion of the Cascade mountains, from Lake Chelan southward nearly to the Oregon boundary. The region actually involved in the Blewett district was not visited but many of the same formations occurring here were studied in other parts of the region examined. The Pre-Tertiary formations are not differentiated but simply described as the "crystalline rocks" lying unconformably beneath the later sediments and lavas, and the Tertiary formations now known as Swauk and Roslyn were grouped together under the general term Kittitas system. Professor Russell says, however (page 20), "Future study may show that this system should be sub-divided but as only a small portion of the region it occupies was traversed by me the classification here proposed will be sufficient for present needs." Resting unconformably upon the Kittitas system are a series of lavas which he calls the "Columbia river lava" and above these are fresh water lake beds, which he correlates in age with the John Day beds in Oregon. All of these formations taken together form the bulk of the Cascade range, whose age he provisionally placed as Post-Miocene. No reference is made to any of the ore deposits on Peshastin creek. A list of fossil leaves collected from the Kittitas strata near Wenatchee and identified by Dr. F. H. Knowlton is given.

BETHUNE, GEORGE A., Mines and Minerals of Washington, Annual Report of George A. Bethune, First State Geologist, Olympia, Washington, 1891.

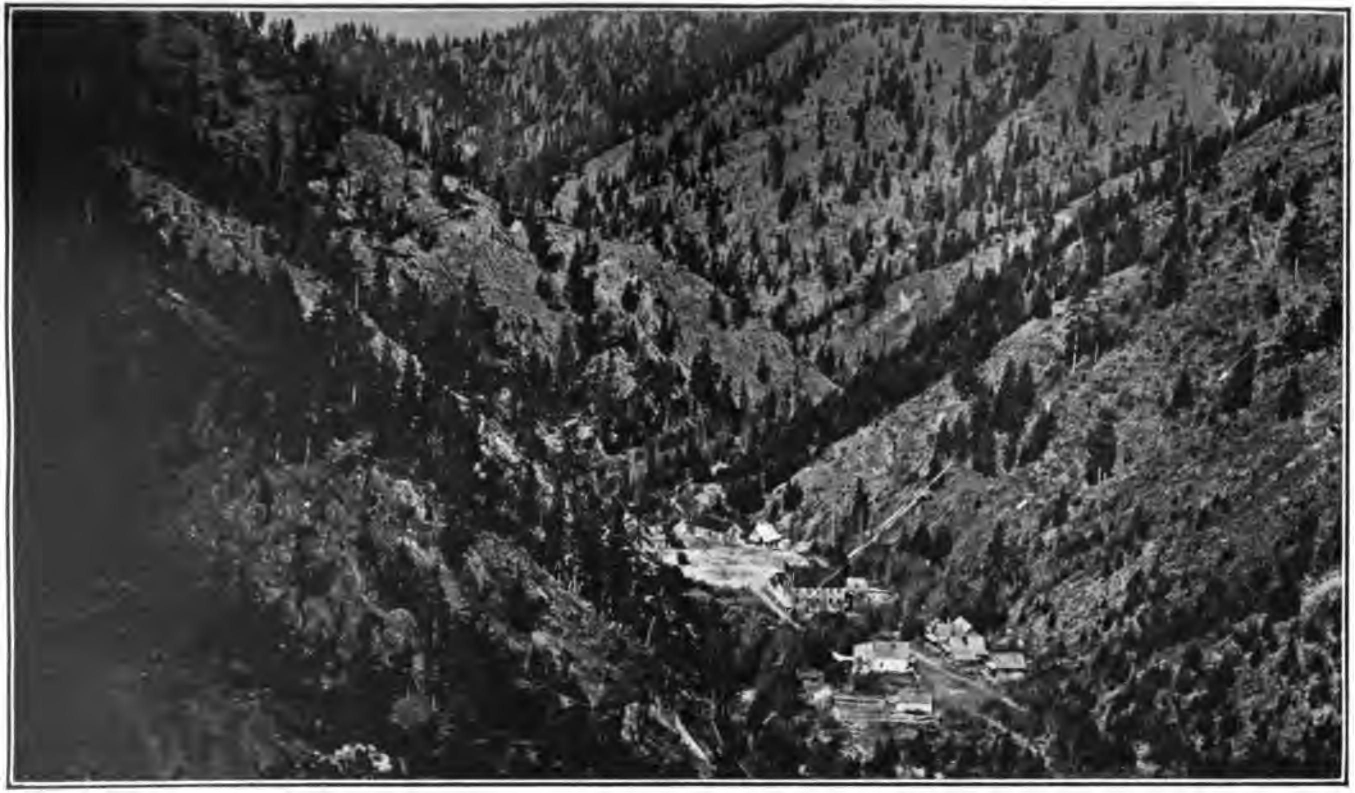
This report does not describe the geological features of the region. On page 92 he gives a very short account of the properties in the Peshastin district, without discussing the ores. Some mention is made of the early history of the camp.

RUSSELL, ISRAEL C., Preliminary Paper on the Geology of the Cascade Mountains in Northern Washington, 20th Annual Report, U. S. Geological Survey, 1898-99, Part II, pp. 83-210. Plates 8-20, Washington, D. C., 1900.

In this paper Professor Russell discusses the geology of an area aproximately sixty miles in width and extending from the Northern Pacific Railway, where it crosses the Cascade mountains, northward to the United States-Canadian boundary, a distance of about 100 miles. The Blewett district was visited and the formations studied. The granodiorite and serpentine, as well as the greenstones and slates, are described; the latter two corresponding to what are now known as the Hawkins and Peshastin formations. The Tertiary sandstones, which were originally called the Kittitas system, are now subdivided into two new formations which he designates as the Swauk and Roslyn, and which are separated by an extensive series of lava flows.

Upon palaeobotanical evidence they are both assigned to the Eocene. He considers the complex mass of the Cascade mountains to have undergone erosion during the late Tertiary times, and then to have been uplifted to an elevation of about 7,500 feet as a complex warped dome. The relations of the larger valleys to uplift are discussed in detail as well as the areal distribution and the geological work of the glaciers.

Considerable attention is given to the discussion of the ore deposits in the Blewett district, both placer and quartz. His description of these deposits can best be stated in his own words (page 208), "The country rock in the Peshastin district is mainly schist, serpentine, greenstone, etc., which has been much disturbed since the mineral bearing veins were formed. On account of the disturbances that have affected the rock and the small extent of the veins, most of which are rather 'gash veins' than true fissure veins, extensive and continuous bodies of gold-bearing quartz are scarcely to be expected. Rich quartz has been discovered, however, and at least one of the mines has paid well. A belt of rocks in which the mines at Blewett occur, extends for some eighteen or twenty miles to the westward, about the southern base of the central granitic core of the Wenatchee mountains and northward to beyond Leavenworth and has been found to carry gold at numerous localities. This same complex belt of rocks has been found also to contain copper, nickel, cobalt, and mercury (cinnabar) in many places. It is safe to say that several thousand mineral locations have been made in this region, more especially along Negro and Ingalls creeks, on the headwaters of Icicle and Fortune creeks, and in the mountains from which flow the several branches of the north and middle forks of Teanaway river. Only a few of these prospects have been opened so as to show what the conditions really are, and with the exception of a few locations on Negro creek, no actual mining operations have been undertaken. The fact that so few prospects have been developed, and the total absence of paying mines in 1898, lead to the inference that this region is not promising from the miner's point of view. Although rich ores seem to have



Town of Blewett, looking north. Situated in Peshastin Valley.

been discovered in many instances, no large bodies of such ores have as yet been revealed. To the geologist the main difficulty seems to be the many disturbances that have affected the region since the deposition of the ores. The numerous faults and the large areas where the rocks have been crushed and displaced make it evident that only the most careful exploration, guided by a critical knowledge of the geological conditions, can hope to lead to success."

HODGES, L. K., Mining in the Pacific Northwest, published by the Seatle Post-Intelligencer, pp. 70-76, on the Peshastin District, Seattle, 1897.

This paper describes the general geography of the Blewett and Negro Creek Mining Districts. Very little definite information is given concerning the geology or nature of ore deposition. Considerable attention is given to a discussion of the early attempts at mining and the development of mining operations up to the year 1897. A small map is included showing the position of the various mining claims at that time.

KNAPP, A. E., The Metaliferous Resources of Washington, Peshastin District, pp. 94-98, Annual Report, Vol. 1, Washington State Geological Survey (Landes), 1901, Olympia, Washington.

This paper notes in a general way the character of the formations and the veins included in them. The ores are said to be free milling and concentrating, and to occur as pocket veins, or enriched zones along lines of crushing. A short description is given of the mining operations carried on in each of the important claims.

SMITH, GEORGE OTIS, AND WILLIS, BAILEY; Contributions to the Geology of Washington, pp. 1-97, Professional Paper No. 19, U. S. Geological Survey, Washington, D. C., 1903.

In this paper the results of detailed areal geological work are presented. A map showing the areal distribution of the formations west of Blewett is included, and the formations which were formerly designated as the "crystalline rocks" are now subdivided into the Easton schist, Peshastin formation, and Hawkins formation. The Tertiary, sedimentary, and igneous rocks are also described and their structural relations discussed. Special attention is given to the physiography and the development of the topographic features. The conclusion is drawn that there were two periods during Tertiary times of complex warping of the Cascades, separated by a period of peneplanation. The evidence supporting this conclusion is given, as well as the problems involved in the second period of warping or final uplift of the Cascade mountains. No discussion of the ore deposits is attempted.

SMITH, GEORGE OTIS; The Mount Stuart Folio, No. 106, Washington, U. S. Geological Survey, Geology Surveyed 1898-99; Washington, D. C., 1904.

This folio represents the detailed areal geological mapping of about 800 square miles and in the northern part of this area is situated the Blewett mining district. All of the formations are described, ranging from the earliest metamorphic rocks up to latest Quaternary, including glacial and alluvial deposits. The different structural features are discussed and an outline of the geological and geographic history is given. The quartz and placer deposits on Peshastin and Negro creeks are described, and their origin and geological relations discussed. Especial attention is given to a discussion of the Warrior General mine, which he says is located (page 9) "In a zone of sheared serpentine where the mineral bearing solutions have found conditions favorable for ore deposition. This mineral zone has a general east-west course and extends from east of Blewett across Peshastin creek, up Culver gulch and across the valley of Negro creek.

The Warrior General vein has a trend of north 70° to 80° east, and is very irregular in width. In the walls the serpentine is often talc-like in appearance while the compact, white quartz of the vein is sometimes banded with green talcose material. Sulphides are present in the ore but are not at all prominent. The values are mostly in free gold, which is fine, although in some of the richer quartz the flakes may be detected with the unaided eye." Regarding the placer deposits of the Peshastin district, Dr. Smith says: "The gravels appear to be gold-bearing throughout and the gold is rarely uniform in distribution. The largest nuggets are found on the irregular surface of the Pre-Tertiary slate which forms the bed rock * * * The largest nuggets found in the Peshastin district are less than an ounce in weight. * * * The Peshastin gold is fairly coarse and easily saved. The gold is high grade, being worth about $18.00 an ounce."

SMITH, GEORGE OTIS; Geology of the Snoqualmie Folio, Washington, No. 139, U. S. Geological Survey, Geology Surveyed 1899 and 1902, Washington, D. C., 1906.

In a general way the formations occurring in this quadrangle, which is situated directly west of the Mount Stuart quadrangle, are the same and whatever may be said in regard to the more important geological features of one applies to the other.

GEOLOGY AND ORE DEPOSITS OF THE BLEWETT MINING DISTRICT.

CHAPTER I.

PHYSIOGRAPHY.

TOPOGRAPHY.

GENERAL STATEMENT.

The topography of the area involved in the Blewett district is a part of the general topography of the eastern portion of the Cascade mountains, south of the Wenatchee valley and north of the Yakima. This region represents a broad spur of the Cascade mountains extending in a general east to northwest direction from Columbia river up through Mount Stuart and thence northwesterly over the main divide to the western slope of the mountain. One of the striking features of this broad spur is a ridge known as the Wenatchee mountains, which begins near the Columbia river, at an elevation of about 1,000 feet and gradually increases until it culminates in Mount Stuart, at an elevation of 9,470 feet, and then decreases until it reaches the main divide of the Cascades. This ridge forms the divide between the two valleys just mentioned and, up near its crest, head some of the large tributaries to Yakima and Wenatchee rivers. Among these on the north are Icicle, Ingalls, Negro, and Peshastin creeks. Throughout the larger part of this region the mountains are bold and rugged and often impassable. The ridges are narrow with steep slopes and canyon-like valleys, with occasional cascades along their courses. The lower portions af the larger valleys are wider and in many places alluvial plains have been built up. The general altitude of the peaks and ridges within this area decrease from the main divide on the west to Columbia river on the east as well as from the crest of the Wenatchee mountain ridge northward and southward to the valleys of Wenatchee and Yakima rivers.

The Blewett mining district lies about ten miles north of the Wenatchee mountain crest and twenty miles east of Mount Stuart, but within the drainage basin of Peshastin and Negro creeks. The topographic features of this region present bold, rugged appearances, not so steep or precipitous, however, as farther to the west near the main divide, nor so low and rounded as near the Columbia river. Conforming to the general easterly slope of the Cascades in the broad area just described, the general level of the higher ridges and peaks decreases from an elevation of 5,500 feet in the southwest to 5,000 feet in the eastern portion of the map. Two large valleys, which join near the north part of the area and which have numerous smaller canyons and gulches draining into them, stand out as a prominent feature of the topography. These smaller creeks and gulches are characterized by steep slopes and high grades, and occasionally present small waterfalls.

DRAINAGE.

The larger part of the drainage within the area of the Blewett district finds its way into Peshastin creek and its tributary, Negro creek. A very small area in the northwestern part of the district drains down to Ingalls creek, which in turn, about five miles below Blewett, drains into Peshastin creek, and the latter about eighteen miles below Blewett joins Wenatchee river, which a few miles below, empties into Columbia river at the city of Wenatchee.

Peshastin creek has a high grade, approximately 180 feet to the mile, within the north and south limits of the district. To the south, above Blewett, it receives the drainage from Shaser and Tronson creeks. At a point on Peshastin creek four miles north of the Wenatchee mountain divide it becomes a small mountain stream and the grade from there to Blewett is about eighty feet to the mile. From the intersection of the western boundary of the map and Negro creek to the mouth of the same creek the grade is approximately 480 feet to the mile. The smaller streams tributary to Peshastin and Negro creeks, such as Ruby creek, King creek, Culver Springs gulch, Culver gulch, and Bear creek, carry some water throughout the year and during the springtime often carry considerable volume.

No official records of the volume of water passing through Peshastin creek at Blewett have ever been made. However, according to estimates made by General J. D. McIntire, who was in charge of the La Rica property for a time, the flow during the dry season amounts to ten cubic feet per second. In the winter it is much greater.

FORMS OF THE SURFACE.

The lowest elevation recorded within this district is 2,150 feet at the north end of the map on Peshastin creek just below where it is joined by Negro creek and the highest elevation is 5,650 feet in the southwestern corner. On the high ridge between Shaser and Negro creeks, at the head of Bear creek, at the point where this maximum elevation was obtained, this same ridge swings northeasterly and becomes the divide between Negro creek on the north and Peshastin on the south and east. King creek, Culver Springs gulch, and Culver gulch head along the eastern slopes of this divide, and Bear creek along the northern. At the head of Culver gulch on this ridge is located the United States mineral monument for the Blewett-Negro creek mining district, at an elevation of 4,216 feet. The highest elevation reached on the divide between Negro and Ingalls creeks is 5,000 feet, and from the crest down to the valley floor the slopes are exceptionally steep. On the east side of Peshastin creek at Windmill Point the elevation attained is 4,250 feet, and on the high knob south of King creek 4,650 feet.

GLACIATION.

No evidence of the area involved in this district ever having been glaciated could be found. There is direct evidence, however, of glaciation in the surrounding region. Such valleys as Icicle and Ingalls show evidences of having been occupied by glaciers as well as Peshastin creek below its junction with Ingalls creek. These glaciers had their gathering ground high up near the crest of the Cascade mountains and especially in the region about Mount Stuart, and from there advanced downwards and partially filled the pre-glacial stream valleys and then finally, after their retreat, left moraines and erratic bowlders strewn along their former path.

CLIMATE.

The climate at Blewett is representative of the intermediate altitudes on the eastern slopes of the Cascades. The winter temperature is higher than at Wenatchee, Leavenworth, or Ellensburg. The summer heat, while sometimes considerable, is not so great as that at the above mentioned places, because of the influence of the colder air currents after having passed over the more elevated and sometimes snow-capped ridges to the west. The annual rainfall is higher than at either Ellensburg or Wenatchee. Snow begins falling late in November but generally disappears from the valley about Blewett by April, and from the higher ridges late in May. No official records of the temperature, rainfall, or snowfall have been kept at Blewett. The nearest points at which these records have been kept are Cle Elum, Lake Kachess, and Lake Keechelus. The following table has been prepared by Professor E. J. Saunders, of the University of Washington:

LOCATION	Elevation. Feet	Annual precipitation. Inches	Annual snow fall. Inches	Mean yearly temp. Fahr.	Mean temp. warmest month	Mean temp. coldest month
Lake Keechelus	2,479	61.90	280.7	42.4	98	16
Lake Kachess	2,235	56.09	167.0	42.4	60	20
Lake Cle Elum	2,171	81.24	113.0	....	....	....
Wenatchee	1,169	15.50	75.9	48	70	27
Cle Elum	1,930	26.60	79.5	45	64	28

The highest temperature ever recorded at Wenatchee was 104° ; at Cle Elum, 101°. The lowest temperature ever recorded at Wenatchee was —16° ; at Cle Elum, —24° ; at Ellensburg, —29°. The elevation at Blewett corresponds most closely to that of Lake Kachess, but because of the greater distance from the summit of the Cascades the mean yearly temperature probably corresponds more closely to that of Cle Elum; the annual rainfall is probably intermediate between that of Wenatchee and Cle Elum; the annual snowfall perhaps as great as that of Lake Cle Elum.

VEGETATION.

Originally this entire district was covered with timber consisting chiefly of the following varieties: the tamarack, the yellow pine and the red fir. These forests are open in character, except on the lower slopes and about the stream bottoms, which are generally heavily covered with thickets and small shrubs with some of the larger trees scattered among them. In Peshastin valley and up Culver gulch much timber has been removed for local building purposes and for mine timbering. Above the altitudes of 5,000 feet the trees become smaller but not so small as the stunted forms on the much higher altitudes outside of the map.

RELATION OF THE PRESENT TOPOGRAPHY TO THE GENERAL GEOLOGY.

The explanation of the present topography and the various relations of the streams and valleys to each other is in a large part to be explained from a study of the geological conditions in a much larger portion of the Cascade mountains, of which the Blewett district is only a very small fragment. Fortunately, geologists with a much wider experience have studied this larger area in detail and have been enabled to arrive at some definite conclusions. A discussion of the geological events concerned in producing these changes will not be considered here, except in so far as they relate to the principal drainage features within the area involved. As has been stated before, one of the most important factors connected with the final uplift of the Cascade mountain mass was the differential warping of the uplifted dome, which in this particular portion of the Cascades resulted in the formation of the long ridge now known as the Wenatchee mountains. Immediately upon the initiation of the upward movement drainage lines began to adapt themselves to the new conditions and as a result such streams as Ingalls creek and Peshastin creek developed. As the Wenatchee mountain mass kept rising the grade of the newly developed streams was increased and they soon encountered in their downward cutting rock of differential resistance. As a result the small lateral streams began to excavate their channels in those rocks which would offer the least resistance, giving rise to such streams as Negro creek, Ruby creek, Shaser creek, and Tronson creek. As time passed on this method of development increased until the present topographical features were attained. Outside of the area of this map many of the topographic features due to this cause have been modified by the action of the glaciers. Within the area of this district they have played no direct part in developing the present topography.

CHAPTER II.

GENERAL GEOLOGY.

INTRODUCTION.

The general geology of the Blewett mining district is but a small fragment of the geology of the eastern portion of the Cascade mountains. Because of this fact, the elucidation of nearly all of the intricate geologic problems involved in this district must be partially sought for in the broader field surrounding this district. A part of this broader field has been studied and areally mapped and published in the Mount Stuart and Snoqualmie geological folios. Hence all of the formations occurring in the Blewett district have been previously described, and in the following discussion an attempt will be made to represent in as much detail as possible the more salient features of each formation and their relation to the broader field outside, and the problems involved in the deposition of the ore. Many of the formations occurring outside of the district do not occur within it. The oldest formation found in this district consists of a lower series of quartzites, slates, quartzite-conglomerates and cherts, overlaid apparently unconformably by an upper series of brecciated lavas and tuffs, together with massive igneous rocks. No fossiliferous evidence has been obtained to determine their age, but from their close resemblance to formations in the north,* whose age is known, they are provisionally assigned to the Carboniferous. After their deposition they underwent deformation resulting in their metamorphism. Accompanying this deformation were great intrusions of peridotite and other associated basic igneous rocks which were later more or less altered to serpentine. After this, erosion became active and deformational movements produced a warping, allowing great drainage basins to form, and in these basins were accumulated sandstones and shales belonging to the Swauk formation and attaining a maximum thickness of perhaps 5,000 feet. Cutting through the Swauk sandstone are numerous diabasic dikes leading up to and connecting with surface lava flows of the Teanaway basalt. Also there are intruded into the Swauk and the older rocks as well, plutonic masses and sills of gabbro which were probably injected either just before or contemporaneous with the diabase. Overlying these are later sedimentary lake deposits known as the Roslyn formation. Above these are still younger sediments and lavas and tuffs but no rocks younger than the diabase occur within the Blewett district proper with the exception of Quaternary gravels and alluvium.

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*Ann. Report, Geological Survey, Canada, New Series, Vol. 7, 1894, pp. 37 B-49-B.

CONTACT SCHIST.

The rock referred to in this report as a contact schist has been recognized at but one locality in this district. About one mile south of Blewett on the west side of Peshastin creek at Kendall creek it outcrops near the road. A few hundred feet above this outcrop where the county road crosses Peshastin creek a long narrow dike of granodiorite, trending nearly east and west, occurs. On both sides of Kendall creek and in the creek itself this schist stands out prominently. On the south it lies in contact with the granodiorite, and on the north with the peridotite. In general appearance it is distinctly banded and filled with small gash seams of quartz. Each of the individual bands or lamellae ranges from one-fourth to one-sixteenth of an inch in thickness, and consist of fine grained, gray chert-like appearing material, alternating with white quartz. Occasionally bands of mica-schist occur. As a rule the bands are twisted and contorted but sometimes are nearly straight with a persistent strike and dip. Observations were made on the bluff on the north side of Kendall creek, where the strike was found to be north 20° west, and the dip about 75° to the southwest. On the south side of the same creek and at the creek level, a small tunnel has been driven in along the strike of the formation for a distance of thirty feet. In the tunnel the quartz bands predominate. They are not persistent in character and are rarely ever more than two inches in thickness and pinch out both above and below. In addition numerous stringers of quartz of the same general character as those occurring in bands cut obliquely across the strike and dip of the formation. No economic value attaches to the quartz on account of the prevailingly low assays obtained. The total area of the entire outcrop is not over 5,000 square feet.

While this individual outcrop does not appear on the geologic map of the Mount Stuart Folio, yet similar rocks are mapped and described near the contact of the Mount Stuart granodiorite massif with the serpentine, in the vicinity of Mount Stuart. In that region Dr. Smith found apophyses of the granodiorite and also of the serpentine extending into the schist and hence concluded that it represented some formation older than the serpentine which had been metamorphosed possibly by both. In the outcrop described in this report the serpentine is clearly intrusive in the schist. The main mass of the granodiorite dike is also included but no small apophyses were seen extending from it into the schist, although they may occur and have escaped detection. No definite age can be assigned to this rock, except that it is older than the peridotite or serpentine. It may represent an extremely metamorphosed phase of the Peshastin or Hawkins formations or it may possibly represent still older rocks. It is apparent, however, that this extreme phase of metamorphism has been produced by the granodiorite more than by the peridotite as the contortion and twisting becomes more pronounced the nearer the contact with granodiorite.

This rock is described first among the geological formations represented and is placed at the foot of the geological column in the legend on the areal geological map, but that does not necessarily indicate that it is positively older than the Peshastin or Hawkins formations. It has been designated the "Contact

Schist" because rocks* similar in character and geologic relations have already been described as such by Dr. Smith in the Mount Stuart Folio.

PESHASTIN FORMATION.

Areal Distribution.—When not covered over by later sediments, the series of rocks grouped together under the general term Peshastin formation form an important part of the areal geology in that portion of the Cascades near Mount Stuart. Outcrops of rock similar in character occur in various parts of the Northern Cascade mountains, which may be a part of the same general formation described here, but at the present time there is no direct evidence to make a definite statement. In the Mount Stuart and Snoqualmie quadrangles, where the geology has been carefully mapped, the areal distribution of the rocks belonging to this formation is definitely known. Surrounding the southern part of the Mount Stuart massif of granodiorite there is a fringe of igneous and metamorphic rock ranging from three to ten miles in width and extending from Peshastin creek on the east, westward along the Chelan-Kittitas county boundary for a distance of about twenty miles. This belt is overlain to the south and east by later sediments belonging to the Swauk formation. Within this belt the outcrops of the Peshastin formation occur as irregular shaped patches enclosed in serpentine and gabbro.

Within the Blewett district proper the Peshastin formation occupies a prominent position on the areal geological map. Three separate outcrops are represented: The largest has an area of about two square miles and lies to the north of Blewett on both sides of Peshastin creek and over the ridge on Negro creek and from there continues to the north boundary of the map. It outcrops on both sides of Negro creek to a point about one and one-fourth miles from its mouth and then extends westward as a narrow belt about 1,500 feet wide along the south side of the ridge between Negro and Ingalls creeks to the western limits of the map. Two other very small outcrops occur, the larger of which is situated in the southeast corner of the map on the south side of Sheep mountain as an elliptical shaped mass, apparently pitching downwards at a very low angle beneath the Hawkins formation. The second patch occurs at the head of the south fork of King creek.

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*Geology of Mt. Stuart Folio, p. 5, U. S. Geological Survey, 1904, Washington, D. C.

GENERAL DESCRIPTION.—The rocks composing the Peshastin formation are prevailingly black slates and fine grained, dark colored quartzites. There are subordinate proportions of black grit, ranging to a fine conglomerate, together with occasional narrow bands of green and red chert and ferruginous slate. This entire series has undergone more or less extensive metamorphism, but the original character of the sediments is in most places plainly discernible. On the east side of Peshastin creek about one-fourth mile below Culver gulch, a quartzitic conglomerate belt occurs having an average thickness of nearly 100 feet, but owing to the deformation which it has undergone it is more or less crushed and faulted, and in places neither the upper nor lower limits could be traced. Originally this rock was a fine grained conglomerate, grading into a coarse sandy grit. The pebbles contained in it have in places been more or less drawn out elliptically, but often retain their original shape. They range in size from ordinary sand grains to one-half inch in diameter. These pebbles consist of blue, white and dark gray quartz, probably representing grains of a former quartzite, of red and brown chert, of black volcanic glass, of dense, hard compact greenstone and occasionally of much altered white to light gray material which originally may have been volcanic tuff. In some of the hand specimens water worn pebbles of black clay slate were observed. The whole mass contains more or less secondary pyrite impregnated through it. Many of the pebbles, especially of the quartz and chert, are noticeably cracked and fissured and filled with secondary quartz. This fracturing apparently occurred prior to the formation of the pebbles, while they were still a part of some pre-Peshastin massive rock. The conglomerate masses have been metamorphosed along with the other members of the

Peshastin formation, and in consequence have suffered considerable shattering. These quartzitic conglomerates also occur interbedded with slate and quartzites as may be observed on the north side of Negro creek, about two miles above its mouth.

The clay slates are extremely fine grained, ranging in color from a bluish-gray or gray to black, and have a close, crystalline texture. They tend to cleave in parallel plates of varying thickness but the size of the plates is very irregular, due to numerous but less prominent joint planes which intersect the slate mass, in various directions. Often the slates change in character, indicating changes in sedimentation during their deposition and prior to their metamorphism. Commonly bands of various thicknesses of fine grained quartzite alternate with the slate and grade into each other, showing distinctly the original stratification bedding plane. Often the clay slates appear more massive in character, and instead of being characterized by cleavage planes, possess a fissile character, become coarser grained, and break with a conchoidal fracture. The zones of most prominent shearing are approximately parallel to the stratification or bedding plane. Near the mouth of Negro creek and along the county road from this point to Blewett excellent exposures of the strike and dip, cleavage and joint planes may be obtained. The average of about thirty different observations taken on the strike and dip were—strike, N. 5° W. and dip, 80° to 85° to the southwest.

HAWKINS FORMATION.

AREAL DISTRIBUTION.—The rocks which are described as the Hawkins formation constitute a prominent feature of the areal geology within the Blewett district proper, and are a part of a much broader belt extending east and west from Mount Stuart. They have been areally mapped in the Mount Stuart and Snoqualmie quadrangles, where they may be seen to extend as more or less disconnected patches from Peshastin creek on the east, westward to Mount Hawkins, and thence northwesterly. In all of these localities they are intimately associated with the Peshastin formation and with a peridotite intrusive mass and undoubtedly would have a much wider areal distribution if the later overlying Tertiary formations were removed.

Within the areal geological map accompanying this report the Hawkins formation is well represented. In the western portion of this district three separate areas have been mapped. One of these has an area of about one square mile and lies partly on the north and partly on the south of Negro creek. In the southwestern corner there is an area of about two-thirds of one square mile, and just east of this another area about 1,500 feet in width and one mile in length. On the east side of Peshastin creek the Hawkins formation occupies an area of about one-quarter of a square mile, and includes the rocks forming Windmill point. South of this an area averaging 600 feet in width and one mile in length crosses over to the west side of Peshastin creek and extends up to Sheep mountain. In addition to those already mentioned, several outcrops occurring in the serpentine have been mapped, and numerous patches too small to represent occur, but have not been separated from the serpentine.

GENERAL DESCRIPTION.—The rocks grouped under the general term Hawkins formation constitute the bolder crags and pinnacles such as Sheep mountain, Iron mountain, and the high ragged ridge between Culver gulch and Negro creek. The hard and compact texture of the materials composing these rocks have resisted weathering compared with the more easily eroded adjacent rocks. These rocks when viewed from a distance have a black, basaltic appearance and as a rule are devoid of much soil. On the north and upper side of Culver gulch this formation outcrops prominently with a broken surface and sharp crag-like crest. Below it outcrops the serpentines, in which are included some of the richest veins of ore in the district. These veins extend over into the Hawkins but as far as can be determined the ore values decrease. The rocks composing this formation are represented by volcanic breccias, tuffs, and intercalated volcanic flows. These are nearly everywhere intricately

A—General view of district, looking west from the hills east of Peshastin creek. Culver gulch in foreground. Negro creek valley immediately back and Ingalls creek valley in the rear.

B—North side of Culver gulch, showing outcrops of "Nickel Dike."

mingled, as may be seen on the eastern side of Peshastin creek, and on the slopes leading up to Windmill point. In the exposures here represented great masses of rock composed of angular and partially worn fragments occur. Among these bowlders are gabbro, diabase, diorite and andesite porphyry; and irregular shaped fragments of scoriaceous material and volcanic tuff. These are partially cemented by silica and are intersected by secondary veins of quartz and calcite. In some places the fragments composing this mass are made up of quartzites, slates and metamorphic grits, and closely resembling those in the Peshastin formation, occurring on Peshastin creek just north of Blewett. In still other places fragments of greenstone occur intermixed with the other material. The size of these angular fragments ranges from small grains up to twenty or more feet in diameter, the larger bowlders being for the most part composed of gabbro porphyry nearly free from alteration and apparently genetically associated with the basic flows.

The interbedded flows are generally broken and in places tuffaceous and have scattered through them fragments of the rocks just mentioned. When observed from a distance, these rocks appear black, but on closer examination they are seen to be a dark green. Near the contact with the serpentine they are often white, due to the coating and impregnations of magnesium carbonate, which has been derived by solution from the serpentine mass. An instance of this may be seen in the mass leading up to Sheep mountain. On the sheer walls forming the crag of this mountain these rocks are deeply stained a bluish-green and in places contain small specks of chalcopyrite. The fragments composing this mass when examined are seen to be composed of brecciated fragments of igneous lava, tuffs, and cherts.

PETROGRAPHY.—An examination of about thirty hand specimens collected from different outcrops of the Hawkins formation, occurring within this district, shows many variations in the character of the material composing this series of rocks. The majority of the specimens are found to be metamorphosed diabasic rocks, and their corresponding lava equivalents. A typical instance of this diabasic phase is well represented by specimen No. 1143. To the naked eye it appears to be a massive, heavy, gray rock of medium grain and resembles very closely some of the gabbro phases of the peridotite mass, in fact they may be in part small apophyses of the latter injected into the Hawkins formation. They are made up of about equal amounts of feldspar and hornblende in small, allotriomorphic crystals averaging about one millimeter in size. Under the microscope these feldspars prove to be a much altered plagioclase having the chemical composition of bytownite. The hornblende is dark brown and altered to serpentine and chlorite. A very small amount of nearly colorless augite is present.

An examination of several specimens taken from the brecciated lava flows presents a fine grained, gray rock with many conspicuous, white rounded crystals embedded in it, ranging in size from one to three millimeters. Under the microscope the slide is seen to be composed of an intricate mixture of secondary alteration products, consisting of quartz, mica, calcite, and chlorite, with occasional portions of the original unaltered feldspar crystals. These alteration products represent what originally were augite, feldspar, and some orthorhombic pyroxene. Remnants of augite and plagioclase sometimes occur not very much altered. The large crystals of plagioclase are, when relatively fresh, distinctly zoned, and show albite twinning. Extinction angles were measured on one or two of these crystals yielding values of 37° and 39°. The evidence points to these rocks having been originally basic andesite and basalt flows. These two types constitute the bulk of the igneous material composing this formation.

PERIDOTITE.

Areal Distribution.—Ultra-basic intrusive rocks are well represented as a part of the areal geology in the eastern part of the Cascade mountains. In the Mount Stuart and Snoqualmie folios they constitute the surface rocks over an area of about 100 square miles and lie in a nearly east to west belt, averaging from two to eight miles in width and about twenty miles in length. This belt is situated south of Ingalls creek and north of the ridge known as the Wenatchee mountains. East of Peshastin creek it passes beneath the sedimentary and volcanic rocks; to the west it passes around the southern side of Mount Stuart and through Mount Hawkins, and then swings northwesterly through the Snoqualmie quadrangle into the Skykomish, where it is known to have a wide distribution but has never been areally mapped. Other known occurrences are scattered here and there through the Cascade mountains, and are probably closely related in age. Within the boundaries of the Blewett district, the peridotite, with its resultant alteration product of serpentine, has a larger areal distribution than the rocks of any other formation, approximating three-fifths of the total area. These occur in the south half of the map, with several large blocks of older rock incorporated into them, as well as later intrusive dikes. In the north half of the area the peridotite occurs as a long narrow band which has been forced up into the Hawkins and Peshastin formations.

GENERAL DESCRIPTION.—The formation described in this report as peridotite covers an assemblage of ultra-basic plutonic rocks and their alteration products which occur in various degrees of serpentinization. These rocks vary extremely in character and general appearance, and in some places stand out as conspicuous topographic features. More commonly they form the less rugged ridges, because of the less resistance to erosion. This may be seen by noting the topography on the east side of Peshastin creek, immediately east of the town of Blewett. The lower 1,000 feet—while comparatively steep, is composed of soil, and has rounded, smooth surfaces, while above the 3,500-foot contour the outcrops of the Hawkins formation stand out as bare jagged rocks. The same is true on Sheep mountain when contrasted with the less rugged topography just to the north. On the west side of Peshastin creek, in the vicinity of King creek, Culver Springs gulch, and Culver gulch, the same observations may be made. Iron mountain, at the heads of Bear creek and King creek, stands out as a prominent crag and just west of it on the same ridge lies a belt of serpentine about 1,000 feet wide, forming a saddle or depression, and immediately west of this on the same ridge the topography again becomes rough and broken. Both Iron mountain on the one side of the saddle, and the jagged peaks upon the other, are composed of hardened tuffs and breccias belonging to the Hawkins formation, while the more easily eroded portion is confined to the serpentine in the saddle. On the north side of Negro creek a narrow band of serpentine again outcrops, averaging 500 feet in width and lies along the contact between the gabbro on the north and the slates and quartzites of the Peshastin formation on the south. While the area involved is very small, yet the contrast in weathering can be clearly observed. The conclusion to be drawn is that the peridotite as a rule disintegrates under weathering much easier than does the adjacent formations, and the reasons for this must lie in the physical and chemical character of the rock masses.

The physical and chemical characteristics of the rocks grouped under the general term peridotite present many variations. These apply to the general appearance, color, texture, specific gravity, lustre, fracture, hardness and mineral composition. The effects of weathering upon the peridotite differ with variations in the above mentioned characteristics. The heavy, massive, nearly unaltered varieties are least affected and constitute the more rugged features within the area mapped as peridotite. The softer altered phases of serpentine masses disintegrate more easily, leaving the surface covered with talus material, composed of fragments of serpentine having a somewhat schistose or shaly appearance, with conchoidal fracture and smooth, slicken-sided surfaces. Often the character of the rock changes every few feet, which is due to differences in the texture or character of the minerals composing the original rock, and the resulting variations in the degree of serpentinization. Occasionally the nearly fresh peridotite outcrops over considerable areas, with a massive, dark greenish, porphyritic appearance. Large crystals of bastite, the alteration product of enstatite, are easily distinguishable in a dark, fine grained ground mass. Scattered through such masses often occur irregular shaped patches of variously colored serpentine, sometimes black, and less commonly a pure white, but prevailingly a greenish tint. Often a black, glassy variety may be seen containing small lenses of pure white serpentine, ranging in size from a few cubic inches to several thousand feet. In many cases the contact line between the two are sharp and distinct, but between the serpentine and peridotite there is generally a more gradual gradation into one another. Observations show the black glassy varieties to occur near the contact with rocks of other formations, while the greenish varieties are scattered at large through the peridotite mass. Again, the strictly serpentine phases may extend over large areas and scattered about in them occur irregular bunches of only partially serpentized peridotite. In a great many cases rocks resembling a basic diorite or gabbro porphyry occur intimately associated with the serpentine which also are partially serpentinized. The boundaries of such outcrops are indistinct. They occur in small areas and grade into the main body of the serpentine or peridotite so that it is impracticable to represent these phases on the areal map as distinct from the true peridotite. Examples of these occurrences may be seen in the divide between Culver Springs gulch and Culver gulch, at an elevation of 200 feet above Peshastin creek, and also at an elevation of twenty feet above the same creek along the water flume near Culver gulch. This belt is about 200 feet in width, and extends up the hill for a distance of 200 feet and then pinches out as a wedge. A similar rock outcrops in several places on the south side of the ridge, between Culver gulch and the Draw canyon, and also in that canyon on its north wall. These outcrops lie in the serpentine and seem to grade into it. It is possible that they may represent more acid phases of the ultra-basic magmas, such as gabbros which were intruded into the peridotite mass prior to its serpentinization, and which later were acted upon, along with the peridotite, by the same heated, upward-travelling solutions which serpentinized them. These will be discussed in the petrographical description as the Draw canyon gabbro porphyries. Because of the uncertainty of separating these from the peridotite, and because of the fact that they were apparently differentiations from the same ultra-basic magma, and intruded at approximately the same time, and later serpentinized with the peridotite, it has seemed best to include and describe all under the general term peridotite.

In many cases the line of contact upon the areal map between the peridotite and other formations has been arbitrarily drawn. This is partly because of the resemblance of the peridotite to certain phases of the igneous portions of the Hawkins formation, partly because of certain isolated patches of serpentine within the Hawkins and Peshastin, too small to represent upon the areal map, partly because small blocks of the Hawkins have been incorporated within the serpentine and extremely altered, and partly because of the irregular contact lines, due to the irregular intrusions of the peridotite and the extension of long apophyses of the latter into the Hawkins and Peshastin formations. Often alteration of certain phases of the Peshastin have occurred, due to these basic intrusions, and in several cases slide material has entirely covered the contact. On the east side of Peshastin creek, just east of Blewett, the contact between the serpentine and the Peshastin formations extends up the hillside in a general southeast direction. In many places huge blocks of the metamorphosed Peshastin grits project up into the serpentine, but the contact can be fairly well traced until the Hawkins is reached. Much of the Hawkins below Windmill point is composed of a dark, basic, igneous rock, resembling very closely some of the less altered phases of the peridotite and project up into the latter as isolated blocks which were disconnected from their original position and incorporated into the peridotite at the time of the latter's intrusion. The same is true on the south side of Negro creek, just below the United States mineral monument, along the serpentine-Hawkins contact.

In other localities the contact is sharp and knifeblade-like, as may be observed on the west side of Iron mountain before mentioned. Here the contact is nearly vertical, the Hawkins presenting a vertical cliff, while at its base the serpentine abuts up against it so that a person can stand with a foot on either side of the contact. Throughout the entire serpentine mass many small patches of rock were seen, resembling the Hawkins very closely. Some of these were not over fifty square feet in area. They are apparently blocks of the Hawkins plucked off from the roof of the intrusive mass at the time of the intrusion and caught up and scattered about within it. The smaller outcrops are not mapped as the Hawkins but are included with the peridotite. The large masses such as Sheep mountain and the one extending from the United States mineral monument to Iron mountain are probably included within the serpentine in the same manner as the smaller blocks. In some instances small apophyses of peridotite were injected up into the Hawkins and Peshastin through small fissures, extending up from the roof of the peridotite magma and later disconnected from the main mass of the magma, and are now represented as isolated lenses of serpentine. Instances of this may be observed on the north side of Culver gulch in the Peshastin formation above the Golden Eagle tunnel and on the east side of Peshastin creek, about one mile north of Blewett, and also at the head of Culver Springs gulch, just above the three cabins. The peridotite is cut along with the older and later rocks by granodiorite porphyry and diabase

Special importance attaches to the peridotite from an economic standpoint, as it is mainly within that formation that the majority of the gold-bearing veins are situated. Their relation to the serpentine will be discussed later under the chapter on Economic Geology.

PETROGRAPHICAL DESCRIPTION.—The rocks which are described as peridotites vary more in character than any other formation represented within this district, due chiefly to variations in the chemical character of the magma at the time of the intrusion. Three principal types can be described, namely:

saxonite, pyroxenite, and an extremely basic phase of gabbro. All of these are differentiations from the same igneous magma and have been more or less altered to serpentine.

Saxonite is a variety of peridotite composed primarily of olivine and enstatite. Olivine predominates, composing three-fifths of the mass. No specimens were found in which these minerals were not partially altered to a network of fibrous serpentine and iron oxide. The alteration is seen to have started around the edges of the crystals and to have extended into it along the cracks, where the serpentine fibers occur normal to the long direction of the fracture. The crystals are allotriomorphic and sometimes over five millimeters in diameter. They are nearly colorless, but often show a greenish tint, but never pleochroism. Enstatite, ($MgSi0_3$) occurs sometimes fresh but generally altered to a variety of serpentine known as bastite. These fibers lie parallel to the prismatic cleavage which on basal sections show intersecting angles of nearly 90°. The fractures traverse the sections at all angles. The color ranges from a yellowish to olive green and shows very weak pleochroism. In addition to these two minerals, small amounts of hornblende and augite occur, forming less than five per cent of the whole rock.

Pyroxenite occurs in many places and especially at the head of Culver gulch where the basic rocks show a decrease in the amount of enstatite and olivine and a relative increase in diallage. The diallage is recognized by the occurrence on basal sections of orthopinacoidal cleavage lines, has a dark green color, and occurs in good sized, subhedral crystals partly altered to serpentine. In one crystal chlorite was recognized as a decomposition product indicating the presence of aluminum. Augite is present in small amounts and shows the typical prismatic cleavage. Two thin sections showed crystals cut nearly parallel to the clino-pinacoid, giving extinction angles of 54° and 56°. They are nearly colorless and show no pleochroism. In size they average much smaller than the diallage.

On the ridge between Draw canyon and Culver gulch several

A—General view of mine workings in the upper part of Culver gulch. Diabase dike in the center.

B—Culver Springs gulch with arrastre in foreground, looking west. Iron mountain composed of Hawkins breccias in upper right-hand corner.

specimens of rock were collected which showed to the naked eye very small, white crystals of feldspar, with hornblende and some augite. When examined under the microscope they proved to be basic plagioclase with a composition of about six parts calcium to one of sodium, which places them in the anorthite division of the plagioclase group. Very few of these crystals range over one millimeter in diameter, but they usually show well developed albite twinning, giving symmetrical extinction angles of 38° on sections cut nearly normal to the twinning lamellae. Brown hornblende in subhedral crystals occurs showing pronounced pleochroism and of about the same size as the feldspar. Subordinate amounts of olivine and augite together with magnetite are scattered through the section. Some of these outcrops grade into the strictly pyroxenite and peridotite phases of the mass and are serpentinized along with them. The evidence points to their having been intruded at about the same time. However, other outcrops such as the one occurring along the water flume just south of the mouth of Culver gulch, where the planes of contact with the adjacent peridotite are more sharply defined may possibly have been intruded at a later date along with the Eocene gabbro intrusions.

"NICKEL DIKES."

Areal Distribution and General Description.—One of the characteristic features of the serpentine belt extending in an east-west direction, south of Mount Stuart, is a series of bright red belts varying in width from 100 to 500 feet. These have been described by Dr. George Otis Smith* who considered them to represent lenses of limestone detached from the Peshastin formation and caught up in the serpentine.

Within the Blewett district certain red bands extend east and west through the serpentine and Hawkins breccias but when examined below the surface are found to be serpentine. Other belts such as the one mapped on the north side of Culver gulch extending down to Negro creek, have a different appearance.

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*Mount Stuart Geological Folio, pp. 3 and 4, U. S. Geological Survey, 1904, Washington, D. C.

When examined with the naked eye they seem to be hard, compact, fine grained, reddish colored rocks, containing small, dark, porphyritic crystals of pyroxene, averaging about 1 mm. in size. This phase of the rock, when examined under the microscope, is found to be composed largely of a fine grained ground mass made up of interlocking grains of silica and dolomite, and small, irregular, secondary seams of opal. In some places small crystals of siderite are scattered through the mass. The large porphyritic crystals are chiefly enstatite more or less altered. The character of this rock changes from point to point, occasionally grading into almost pure dolomite.

The origin of this rock cannot definitely be stated, but from its close proximity to the Peshastin formation it appears to represent a portion of that formation composed largely of lime which has been extremely altered by the intrusion of the peridotite which is rich in magnesia. The original limestone may have been dolomitized by the addition of magnesium from the serpentine. The porphyritic phases of this rock are undoubtedly igneous in origin and represent a portion of the original peridotite magma intruded as dikes.

The chemical analysis of this rock was made by Mr. M. C. Taylor and is here inserted:

SiO_2	43.22%
Al_2O_3	1.40
Fe_2O_3	3.20
FeO	2.10
MgO	8.40
CaO	5.44
Na_2O K_2O	0.36
H_2O (above 110°)	0.92
CO_2	35.87
	100.51%

GRANODIORITE.

Areal Distribution.—The areal geology of the region to the northwest of Blewett is characterized by vast outcrops of granodiorite representing the uncovered portion of a great underlying batholith. The western portion of this area forms the Mount Stuart mass and is generally referred to as the Mount

Stuart massif. Surrounding this massif is a belt of rocks belonging to the Hawkins and Peshastin formations, together with serpentines, and cutting through these metamorphic rocks are small apophyses or dikes of granodiorite. Surrounding this belt of older rocks and overlying them are sandstones of the Swauk formation. The Blewett district lies in the middle zone of metamorphics and serpentine, and the granodiorite occurring within it is represented by small, irregular shaped porphyritic dikes, occurring for the most part south of King creek. The larger of these outcrops appear at the surface as a network of connecting dikes, lying on both sides of Peshastin creek and south of King creek, forming a large part of the ridge between that creek and Shaser creek. Extending from these dikes on the east side of Peshastin creek near the south boundary of the district are three small apophyses cutting through the serpentine towards Sheep mountain. A third dike about 300 feet in width and 1,500 feet in length crosses Peshastin creek between King creek and Culver Springs gulch. Just east of this outcrop, a long narrow dike of the same material, extending nearly east and west, outcrops in the serpentine between Sheep mountain on the south and the Hawkins formation on the north. The most northerly outcrop of granodiorite occurs as a long northwest to southeast dike lying on the north slope of Culver Springs gulch. Three other prominent dikes, extending in a general north to south direction, outcrop in the serpentine on the ridge between Iron mountain and the bold rugged pinnacles of the Hawkins formation on the west. In many other places throughout the serpentine mass in this area, small quartz-like appearing outcrops occur, which at times seem to be extremely acid phases of granodiorite dikes but so small that they have not been mapped.

General Description.—The rocks composing these granodiorites dikes vary considerably in appearance. The granodiorite from the Mount Stuart region proper is distinctly plutonic and holocrystalline in character, while the dikes outcropping in the Blewett district range from granodiorite porphyries to andesite porphyries. As a rule the wider the dike the more closely it approaches the plutonic type. The narrow dikes show the effects of more rapid cooling, and generally present well formed, subhedral to euhedral crystals embedded in a fine grained ground mass. Occasionally the feldspar and hornblende crystals have a general elongation in one direction, giving the rock the appearance of lava flows, exhibiting flow structure. The crystals in the larger mass are often of considerable size and subhedral to anhedral, but embedded in an allotriomorphic granular ground mass composed for the most part of quartz and plagioclase, with a very small amount of hornblende. The rock is prevailingly a light gray, with occasionally a bluish-green tint. It is harder and more resistant to erosion than the serpentine and for this reason stands out in contrast to the surrounding rock.

PETROGRAPHICAL DESCRIPTION.—Upon examination with the naked eye these rocks are seen to be composed chiefly of plagioclase, orthoclase, hornblende, and quartz. The light colored minerals predominate. In some of the specimens a very small amount of hornblende is present. In others it makes up at least 30% of the rock. Three distinct phases of this rock occur within the Blewett district, and a separate description of each follows:

Specimen No. 1100.—This rock was obtained from the granodiorite outcrop on the highest point along the ridge between King and Shaser creeks, at an elevation of 4,150 feet. Microscopically, this is a dense, hard, compact rock composed of white crystals of plagioclase and orthoclase, some hornblende and a very little quartz embedded in a fine grained, dark gray ground mass, and has a decidedly porphyritic appearance. The hornblende and feldspar occur in about equal proportions.

When examined under the microscope, there are found in addition to the minerals already described, a small amount of apatite, titanite, and zircon. The ground mass in which all of these crystals are embedded is made up of numerous, very small interlocking crystals of quartz and feldspar, the latter being composed of plagioclase and orthoclase in about equal proportions. Of the larger porphyritic minerals, plagioclase is the most important. It occurs in idiomorphic crystals, ranging in size from 0.3 mm. to 3.0 mm. The crystals are well formed, generally tabular in habit and show well developed albite twinning parallel to the brachypinacoid. Sections which were cut nearly normal to the albite twinning lamellae gave symmetrical extinction angles as high as 27°. These, however, were attained near the center or core of the crystal and as nearly all of these crystals exhibit pronounced zoning or banding, the angles attained near the margin average 18° to 20°. In some of the smaller crystals in which no zoning or banding is present, extinction angles of 15° occur indicating the more acid phases of labradorite, which is a calcium sodium aluminum silicate, where the ratio of calcium to sodium is nearly equal.

Fairly large crystals of green hornblende are abundant. Their shape is generally irregular. In size they range from small, fragmentary crystals less than 1 mm. up to 1.5 mm. and show the usual pronounced pleochroism. They are commonly altered to iron oxide and chlorite.

Orthoclase is found evenly distributed through the rock, but always subordinate to plagioclase. It makes up approximately 10% of the rock and occurs in crystals ranging in size from 0.2 mm. to 3.0 mm. The larger proportion of this mineral, however, is found in the fine grained ground mass.

A few well formed crystals of biotite were observed under the microscope, less than 0.5 mm. in diameter and parallel to the basal cleavage plane. An occasional prism of zircon or apatite was noted. These larger idiomorphic crystals are scattered about embedded in a ground mass made up of very small irregular grains of orthoclase and quartz, which were the last minerals to separate out from the magma.

A second type is represented by a specimen collected from the granodiorite dike which crosses Peshastin creek between Culver Springs gulch and King creek. This differs from the specimen just described in the presence of a larger number of rounded quartz crystals embedded in the finer grained ground mass. The crystals range in size from 0.3 mm. to 2.0 mm. and are generally clear and filled with small, isotropic intrusions. Hornblende is less conspicuous and the feldspars are represented by a larger percentage of orthoclase, though still subordinate to the plagioclase.

The third phase is represented by specimen No. 51-B, which was collected from one of the extremely narrow dikes cutting into the serpentine and Peshastin formations on the south side of Sheep mountain. This specimen is very fine grained, and to the naked eye seems to be made up of feldspar, quartz, and hornblende. Under the microscope the feldspar crystals are found to be mainly andesine, and orthoclase is more common than in the other two specimens just described. Hornblende is more abundant than in the case of the second specimen but not so much as in the first. Very few crystals range over 1.00 mm. in size. They are all embedded in an extremely fine ground mass, composed of a mosaic of quartz and orthoclase. A chemical analysis of this specimen has been made and is inserted in the following table, along with three analyses made by the U. S. Geological Survey and published in the Mount Stuart Folio:*

ANALYSES OF MOUNT STUART GRANODIORITE.

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.
SiO_2	64.04	63.37	63.78	66.40
Al_2O_3	15.58	15.90	16.39	16.10
Fe_2O_3	1.26	1.41	1.12	3.23
FeO	3.22	3.18	2.76	2.18
MgO	3.23	3.33	3.27	3.74
CaO	4.51	4.63	4.07	1.24
Na_2O	4.01	4.05	3.84	4.78
K_2O	2.22	2.10	2.03	1.69
H_2O at 110°	0.19	0.18	0.22	....
H_2O above 110°	1.17	1.16	1.82	1.52
TiO_2	.69	.69	.44	....
P_2O_5	.16	.17	.11	....
MnO	trace	trace	.05	....
SrO	trace	none	trace	....
BaO	.11	.06	.08	....
Li_2O	trace	trace	trace	....
S	trace	trace	trace	....
	100.39	100.23	99.98	100.78

No. 1—U. S. G. S. Mt. Stuart Folio, from southeast slope of Mount Stuart Range, light-colored phase of granodiorite (H. N. Stokes).
No. 2—Mount Stuart Folio, Ingalls creek, darker variety of granodiorite (H. N. Stokes).
No. 3—Mount Stuart Folio, from dike on branch of Icicle creek west of Mount Stuart.
No. 4—Sheep Mountain, acid light-colored granodiorite dike, (M. C. Taylor, University of Washington).

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*Mount Stuart Folio, U. S. Geological Survey, pp. 2-3, 1906, Washington, D. C.

SWAUK FORMATION.

Areal Distribution.—The Swauk formation occupies an area of roughly 1,000 square miles in the eastern part of the Cascade* mountains and west of Columbia river. The belt is irregular in shape, but has an average width of twenty miles east and west and approximately fifty miles north and south, and extends from beyond Wenatchee lake on the north, southward across Wenatchee river and from thence up over the Wenatchee mountains down to the Yakima valley. On the west it lies unconformably upon the older metamorphic and igneous rock and on the east it passes beneath the later Tertiary lavas, as in the vicinity of Table mountain. Locally, within the area of the Blewett district, it outcrops as one large mass, having an area of nearly one square mile in the northeastern corner. In the southeastern corner and the southwestern corner there are two small patches, which beyond the limits of the district are areally connected.

General Description.—The Swauk formation represents a succession of beds of conglomerate, arkose sandstone, and shales, with occasional carbonaceous seams, all of which are more or less interstratified. No broad subdivision of this formation into characteristic upper and lower divisions can be made, except that the massive granite conglomerate generally represents the base. However, the conglomerates which form the base at one locality may correlatively represent some higher member of the series at another locality in the same formation. These beds were deposited in an extensive but irregular shaped freshwater lake during early Eocene time, and owing to the differential warping of the floor of this lake during the process of deposition of the sediments, the character of the materials laid down at the same time varies because of differences in the depth of water in different locations, and the proximity to shore lines. Hence the stratigraphic succession of beds vary from one locality to another, and the correlation of the several members in different localities cannot be accurately made.

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*Russell, I. C., Preliminary Paper cn the Geology of the Cascade Mountains in Northern Washington, 20th Annual Report, U. S. Geological Survey, 1898-1899, Pt. II.

From studies made in several widely scattered areas, it has been estimated that the Swauk formation aggregates a total thickness of 5,000 feet.*

Because of the changes in the area of deposition, during the time that the sediments were being laid down, the various sections would present different thicknesses and when the fact is taken into consideration that subsequent to deposition there was extensive deformation and that a large part of the formation has been removed by erosion, it becomes apparent that the original thickness is not now represented. Hence stratigraphic sections constructed in different localities represent only portions of the entire stratigraphic column of the Swauk formation.

The base of the formation, wherever observed, rests unconformably upon Pre-Eocene rocks. These basal rocks are composed of materials belonging to the Peshastin, Hawkins, the basic peridotite intrusives, and the granodiorite. They have been extensively metamorphosed and the peridotite had been altered over into serpentine and then eroded, prior to the deformation of the region and the formation of a large irregular drainage basin which developed into an extensive fresh water lake. The basal contact rocks consist of conglomerates ranging in size from fine sandy grits to bowlders which are ten feet or more in diameter, and only partially rounded and water-worn. These variations in character give a fairly clear picture of the conditions of deposition. Many of the large bowlders in the extremely coarse conglomerate consist entirely of granodiorite and indicate local, narrow embayments of the lake basin, where the adjacent land masses were being rapidly torn down and eroded and the materials accumulating close to shore on a rapidly submerging lake floor, so fast in fact, that insufficient time elapsed to allow the action of the water to round the pebbles and bowlders. They now represent a recemented mass of granodiorite bowlders, which are often extremely difficult to distinguish from

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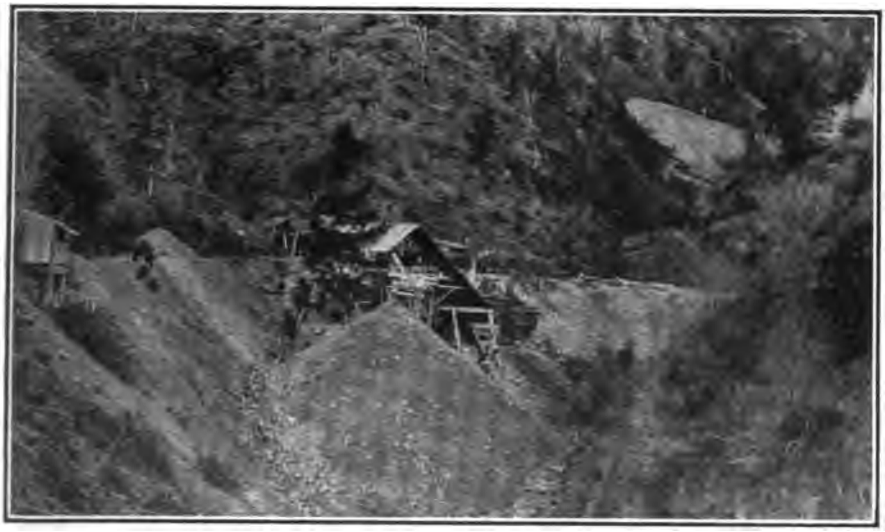
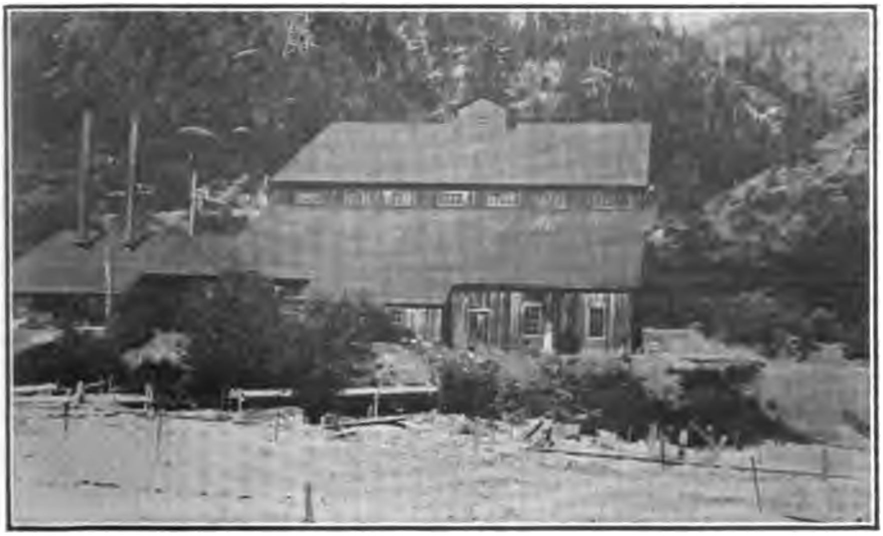
*Mount Stuart Geological Folio, p. 5.



A—General view of Meteor and Peshastin tunnel openings in Culver gulch.



B—Twenty stamp mill at mouth of Culver gulch, looking west. Tailings bin in foreground.

the granodiorite mass itself. In other places the basal conglomerates are made up of well rounded water-worn pebbles averaging from one to six inches in diameter, and from that they range down to fine grits. The pebbles comprising this phase consist of materials derived from all of the older rocks immediately underlying, and from those formations which are not far distant. These consist of slates, schists, cherts, quartzites, intrusive dike rocks and the more or less metamorphosed lavas. In some places many of the pebbles consist of serpentine, indicating that the serpentinization of the peridotites and other basic intrusives had already occurred.

In some instances, black carbonaceous shales are interbedded with the sandstones, but none of them appear to be of commercial importance. In one locality near Shaser creek the basal conglomerates and sandstones are cemented with magnetite. This belt ranges from twenty to sixty feet in thickness and consists in some places of serpentine, containing magnetite, with occasional water-worn pebbles scattered through it. From that condition this belt grades into one where the pebbles become more numerous and ultimately form a black appearing conglomerate entirely cemented by black iron oxide, and this conglomerate when traced upwards into the sandstone finally has for its cementing material silica and ultimately grades into an arkose sandstone or shale.

The middle and upper portions of the formation vary in different places, but in a broad general way consist of massive beds of light gray arkose sandstone, interstratified with layers of shale and occasional beds of fine conglomerate and carbonaceous material.

Within the limits of this district the Swauk formation occurs in three distinct localities all of which are areally connected outside the boundaries of the region. These are represented by an area consisting of about one square mile in the northeast corner of the district, and by two very small patches, one in the extreme southeast corner and one in the southwest. In each of these areas the base is represented, or at least the basal beds for that particular locality. The largest of the outcrops is in the northeastern corner and lies east of Peshastin creek and constitutes the greater part of the rock in which Ruby creek has been eroded. The major portion of the Swauk formation as here represented is locally a light gray, coarse, arkose, massive sandstone showing distinctly the grains of quartz, feldspar, biotite, and muscovite. Very little shale or carbonaceous matter is interbedded, indicating that the sediments had been well washed on the beach where they had been exposed to the action of the waves. The basal members rest unconformably upon the Peshastin, Hawkins, and peridotite formations. While much of the material derived from these formations composes the pebbles and cementing materials of the conglomerates, still the larger part is made up of pebbles and bowlders of the granodiorite. About one-half mile to the north of the map, on Peshastin creek, this conglomerate outcrops on the roadside and represents the typical, bowlder basal conglomerate previously described. The contact as observed between the serpentine and the Swauk near the surface was nearly vertical, or at least with a very steep pitch to the northeast. The contact plane is irregular, showing little knobs of serpentine projecting into the sandstone. Local faulting and slipping has also taken place along the contact, and a good example of this may be seen on the ridge between Negro and Peshastin creeks. The main mass of the formation is composed of light gray, coarse sandstone, massive in character, with very few interbedded shales.

In the southeast corner of the map the sandstone is similar and lies unconformably upon the serpentine. In the southwest corner it rests upon the eroded edges of both the serpentine and Hawkins. It is there composed of conglomerates and typical sandstones. In places the conglomerate is cemented by iron oxide, giving rise to a band or belt of low grade magnetite deposits, locally known as "The Iron Dike." A larger portion of this dike lies just to the south of the boundary of the district and on the north side of Shaser creek.

Correlation and Age.—Within the boundaries of the map no fossils were found. However, at many places throughout the region the Swauk does outcrop and fossils have been found, which are represented by leaves that fell from trees growing along the shores of this lake during the period of its existence. Collections of these were made by Dr. George Otis Smith, who submitted them to Dr. F. H. Knowlton. His determinations* are included in Dr. Smith's report and are here included.

The following genera were collected:

Lygodium
Sabal
Myrica
Populus
Comptonia
Quercus
Ficus
Cinnamomum
Prunus
Diospyros
Celastrinites
Zizyphus
Phyllites

"Of these species a form or variety of only one was previously known, this being *Ficus planicostata*, which is a common species in the Denver and Laramie. Other forms, however, have a more or less close resemblance to certain Laramie, Denver, and Fort Union species, and on this rather insecure basis it is assumed that the age should be regarded as Eocene."

GABBRO.

Distribution and Description.—Numerous intrusive masses of gabbro occur in a belt extending west from Blewett and south of Ingalls creek.†

They do not occur as one continuous mass but rather in several irregular isolated patches, ranging from one to several square miles in area. They have been intruded into the Peshastin, Hawkins, and Swauk formations, and because of their greater ability to withstand weathering as compared with the older rocks, they stand out prominently and form a large part of the ridge south of Ingalls creek and north of Negro and Stafford creeks. Within the Blewett District the gabbro occurs in the northwest part and occupies an area a little less than one-half square mile, where it forms the divide between

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*Mount Stuart Geological Folio, p. 5.

†Mount Stuart Geological Folio, p. 6.

Ingalls and Negro creeks. Here it is intrusive into both the Peshastin slate and serpentine. Just south of the main mass there are two very small apophyses or dikes intrusive into the Peshastin and connected with the present magma not far below the surface. One very small outcrop of coarse grained gabbro occurs above the United States Mineral Monument at the head of Culver gulch at an elevation of about 4,400 feet. These are the only known occurrences of rock which can be definitely assigned to the gabbro intrusions of Eocene time. Many of the partially altered peridotites resemble gabbro and it is possible that they may represent certain phases of the gabbro intrusives. However, these individual outcrops are so small that they have not been mapped but rather grouped in with the peridotites and serpentine. They are also partially altered to serpentine.

PETROGRAPHICAL DESCRIPTION.—The gabbros occurring in this region are fairly constant in character. Most of the hand specimens examined were somewhat altered. They are medium to fine grained rocks, with a light greenish gray color and to the naked eye appear to be composed of light colored feldspars with green and brown minerals scattered among them. Under the microscope these white minerals are seen to be largely basic plagioclase whose composition ranges from Ab1 An5 to Ab1 An6. These crystals average about 1mm. in diameter and sometimes show zonal structure. They are distinctly allotriomorphic and constitute about one-half the mineral content of this rock. The darker minerals were found to be hornblende, augite and diallage. One specimen collected from the summit of the ridge between Negro and Ingalls creeks at an elevation of 4,700 feet consists of about 40% diallage and 10% each of augite and hornblende. Other slides collected further down the ridge near the serpentine contact contained a larger proportion of hornblende, about the same amount of augite and about 10% of diallage. A small amount of what appears to be olivine is present but partially altered to serpentine. Small grains of magnetite are very common. In other slides much of the feldspar is altered to kaolin. Some of the smaller dikes of gabbro cutting up into the Peshastin formation on the north side of Negro creek, have a distinctly ophitic structure and contain hypersthene. The gabbros proper are typically holocrystalline in structure.

DIABASIC DIKES.

AREAL DISTRIBUTION.—Among the prominent geological features represented on the areal map are numerous basic dikes having a general northeast and southwest trend. Their average strike approximates north 25° east. On the eastern side of the Cascades, between Wenatchee river on the north and Yakima river on the south, these dikes outcrop prominently, which may be seen by referring to the areal geologic maps of the Mount Stuart and Snoqualmie folios. Their northeast to southwest strike predominates. These dikes cut through the Peshastin, Hawkins, peridotite, granodiorite, and Swauk formations. Studies made outside of this district give proof that they extend upwards and connect with the lower portion of the Teanaway basalt lava flows, affording ample evidence that those basaltic lavas represent accumulations of basic igneous material which welled up through innumerable northeast southwest fissures and spread over the surface during middle Eocene time. Chemical analyses* made of the diabase dikes and of the Teanaway basalt show them to be genetically associated.

Within the area of this report the Teanaway basalt does not at present exist, but may possibly have done so and have been removed by subsequent erosion. These dikes extend downward nearly vertically and range in width from one foot to 200 feet, varying somewhat with the character of the formation into which they have been intruded. Owing to the original uneven character of the fissures in the serpentine, these dikes vary from point to point, but in the Swauk sandstones and older rocks they are more persistent owing to their harder and more resistant material.

Three prominent dikes outcrop near the head of Culver gulch.

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*Mount Stuart Geological Folio, p. 6.

The one on the north side outcrops at an elevation of 3,840 feet and stands up above the surrounding serpentine. This dike is approximately 700 feet long and has an average width of about seventy-five feet. To the south it tapers down to about twenty feet and then pinches out entirely. At the north end it bends and strikes off 60° west of north for a distance of 300 feet and then disappears. The surface rocks on the south slopes of the canyon are covered with large and small angular blocks broken off from the main diabase mass. An interesting structural feature may be observed at the point where No. 5½ tunnel intersects this dike. The tunnel has been driven on the vein and the latter at the point of contact breaks up into numerous stringers of blackened quartz, showing that the veins existed prior to the intrusion of the dike. On the south side of the gulch, at an elevation of 3,400 feet a narrower dike extends in the direction north 70° west for a distance of about 1,000 feet. The north end of this dike bends to the east and pinches out, and apparently cuts the Pole Pick vein near the three tunnels on the fraction. While these two dikes do not rank among the largest in this area, yet they are important because of their structural relation to the ore deposits to be described later.

Several very prominent dikes of diabase occur near the head of Bear creek, one of these forming the western side of Iron mountain, so named from the basic character of the rock. In the ridges on the south side of King creek there are three conspicuous dikes cutting up through the peridotite and granodiorite. The middle one shows well the irregularity of the dike as it passes from the former into the latter. The fissures through which the molten lava came up to the surface were comparatively wide in the peridotite, while in the granodiorite they were much narrower. This is well shown at the contact where the diabase cuts the other two. Short, narrow wedges of the diabase jut into the granodiorite, which is much fractured and broken, and the portion which extends through it is represented by a long narrow band. In places, in the canyon of King creek, it often becomes impossible to trace its continuation except by connecting isolated projections outcropping through the overlying talus material. On the east side of Peshastin creek and north of Sheep mountain three of these dikes may be seen trending north 70° west, and outcropping in the peridotite. On the same side of the creek, on the ridge leading out to Windmill Point a small dike outcrops, and further north a well defined one about a mile in length crosses Ruby creek and pinches out to the southwest near the contact of the Swauk sandstone with the peridotite. One lone but prominent dike traverses the gabbro on the divide between Negro and Ingalls creeks, and trends in a nearly north to south direction. In many places very small, isolated diabasic outcrops occur but the difficulty in tracing them and distinguishing them from the slide material renders it impossible to represent them on the geological map.

PETROGRAPHICAL DESCRIPTION.—Microscopically, this rock upon fresh exposure has a fine grained and very dark gray colored appearance. It has a high specific gravity and breaks with a conchoidal fracture, and rings when struck with the hammer. The weathered surfaces nearly always present a rusty red color, due to an iron oxide stain, and the surface of the hillside in the vicinity of the dike has a reddish brown appearance due to the oxidation of the disintegrated talus material. Upon close examination with the eye very small crystals of augite can be detected and occasionally larger prophyritic crystals of olivine. Often the clean fractured surface is thickly spotted with brown, lustrous specks, showing strong pleochroism, which appear to be the mineral iddingsite.

Upon examination with a hand lens phenocrysts of feldspar can occasionally be detected but they are universally small. Magnetite sometimes may be seen. In the wider dikes the texture is coarser, specially near the middle, but extremely fine grained toward the edges. All of the specimens collected within the area of the map are fine grained, and have a typical diabasic structure.

Twelve thin sections were chosen from the most representative hand specimens and the following minerals were found to be

present: magnetite, apatite, augite, orthorhombic pyrox
olivine, plagioclase feldspar, and occasionally quartz.

Apatite is not a common constituent and is only sparin
found. It occurs both in long slender and short prisms
seems to be most closely associated with the feldspar and aug
It can be detected by its low, double refraction, high inde
refraction and lack of color.

Magnetite and possibly ilmenite were found in all of the
sections and in several of them in great abundance. They
pear as minute and opaque grains scattered in irregular ma
through the rock without any direct relationship to the o
minerals.

Augite, next to feldspar, is the most important constituen
the rock and is generally fresh and unaltered. It has a
brown color with faint pleochroism. On several crystals wh
happened to be cut nearly parallel to the clinopinacoid, ext
tion angles of 49° were obtained. Many of the crystals c
monly show a zonary structure. Cleavage is well develo
showing as straight lines in sections parallel 010 and 100
intersecting at angles of 88° on sections parallel to the b
None of the crystals show distinct boundaries but rather e
as irregular patches with more or less developed crystal outli

Olivine does not occur abundantly but where represen
shows as clear, fragmental crystals, much decomposed to i
oxide. Occasionally phenocrysts attaining a diameter of 2 m
were noticed, giving pinacoidal and dome outlines as well
straight extinction.

The feldspar present is exclusively of a plagioclase vari
and consists of extremely basic labradorite, occurring mostly
the form of microlite laths. The maximum extinction ang
measured as high as 30°. These small crystals form a netw
and enclosed between them are small grains of augite, givi
the typical insertal structure. Quartz, when present, occurs
very minute grains scattered about along with the augite
tween the feldspar laths. No chemical analyses of this ro

were made but one made by the U. S. Geological Survey and published in the Mount Stuart Folio* is here inserted.

ANALYSIS OF TYPICAL DIKE ROCK FROM NEAR NORTH FORK OF TEANAWAY RIVER.

Compound.	Per cent.
SiO_2	57.21
Al_2O_3	12.99
Fe_2O_3	3.28
FeO	10.13
MgO	1.59
CaO	5.97
Na_2O	3.07
K_2O	1.61
H_2O at 110°	.68
H_2O above 110°	1.08
TiO_2	1.72
P_2O5	.44
MnO	.24
NiO	trace
SrO	trace
BaO	.06
Li_2O	trace
FeS_2	.13
	100.20

QUATERNARY.

ALLUVIUM.—Throughout the eastern portion of the Cascade mountains the Quaternary deposits consist of gravels, sands, silts, and talus deposits, and occasionally large irregular bowlders. These have been eroded away from the high mountain masses, crushed, ground and carried down stream during heavy rainstorms, and finally assorted and deposited over the river flood-plains when the waters receded. Accompanying this process during Quaternary times there was a differential uplift and depression of the land surface with reference to sea level, causing streams to have locally increased or decreased gradients. This produced a silting up of stream valleys in some places and in other places a downward cutting of the stream into the valley floor, allowing the original valley deposits to remain above the level of the stream, forming stream terraces. Nearly all of the larger valleys leading down from the Cascades are mantled over with glacial debris, left upon the retreat of the glacial ice streams. In many cases, moraines may be found showing the position of the ice as it advanced and finally retreated. Hence all these Quaternary deposits may be classed under three main subdivisions: Terrace gravels, glacial deposits, and valley alluvium.

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*Mount Stuart Geological Folio, p. 6.

Within the area of this district glacial deposits are absent. Long tongues of ice came down Ingalls creek, passed into and flowed down Peshastin creek, as may be seen in the moraines along the valley, and in the presence of numerous large granite bowlders, sometimes striated and often perched in precarious positions on other rocks. Above the junction of Ingalls and Peshastin creeks, on the latter stream, no evidence of the action of glaciers could be found, hence it is presumed that the glacial ice never occupied the area involved in this discussion.

Terrace gravels do occur, but not at any considerable elevation above the present valley floor. They may be seen on Peshastin creek below Blewett, extending down as far as Negro creek to the north end of the district. In many places the gravels are mixed with talus materials composed of angular fragments of slates and cherts, making it often impossible to distinguish between the boundaries of the two. On Peshastin creek the pebbles forming these gravels range from the size of a pea to over six feet in diameter, and are composed of materials derived from all of the rocks involved in the drainage basin of Peshastin creek and its tributaries above the place of deposition. Many of these gravels contain placer gold, which will be discussed later in the chapter on ore deposits.

The stream gravels occur along Negro creek to the extreme western end of the district. In several places the width of the valley gravels is several hundred feet. In the western part, on Negro creek, they rest directly upon the Hawkins formation, and east of that upon the Peshastin slates. This is true on Peshastin creek below Blewett and at the junction of the two creeks where Negro creek is cutting a canyon-like gorge in the slates, preventing the local accumulation of gravel until the gradient decreases and the cutting becomes less rapid. Above Blewett the gravels rest upon the serpentine and granodiorite, and about one-half mile south of the map are confined entirely to a bedrock composed of the various members of the Swauk formation. As a rule the gravel lying directly upon the bedrock is fine grained and most of the larger bowlders are found near the surface. All of the smaller creeks emptying into Peshastin and Negro creeks contain more or less detrital material, partially formed by the action of running water, and partially from material collecting on the talus slopes.

STRUCTURE.

The most prominent structural features developed within the Blewett district have been produced by the intrusion of igneous masses and by the deformational movements which this region has undergone along with other portions of the Cascades. The most important structural results of igneous intrusion are the isolation of huge, irregular-shaped blocks of the Hawkins and Peshastin formations, disrupted from larger masses at the time of the peridotite intrusions.

FOLDING.—To a certain extent the old metamorphic rocks have been thrown into a series of anticlines and synclines. While the evidence is not direct, yet it points to the fact that the Peshastin and Hawkins formations are involved in a shallow syncline in the southeastern portion of the map. In the vicinity of Sheep mountain, the Hawkins breccias and tuffs pitch down to the northeast while directly below and south the Peshastin slates are doing the same at the low angle of about 15°. Just north of Windmill point the Peshastin is pitching to the south at a very steep angle. Immediately south and above this locality the Hawkins formation outcrops. The contact is separated, however, by an irregular band of partially serpentinized peridotite. If such a structural feature does occur, large portions of the syncline, including the axis, have been torn asunder by the intrusion of the peridotite. On the north side of Negro creek the Peshastin formation apparently pitches southward beneath the Hawkins. The Swauk sandstone in the southeastern and southwestern portions of the district dips away from the other formations at a very steep angle, and in several places only a short distance farther south it stands nearly vertical.

FAULTING.—No pronounced faulting has been discovered. Many small faults exist which do not seem to be of sufficient extent to be distinguished on the map. They occur mostly in the serpentine. The fissure veins extending east and west along Culver gulch represent faulting and fissuring which occurred early in the geological history of the region, but which were subsequently filled by mineral bearing veins. Suggestions have been made that a later east-west fault occurs near the head of Culver gulch, parallel to the most prominent veins, and which has resulted in the dislocating of two diabasic dikes, one on the north side of the gulch from that on the south. A detailed examination, however, seems to indicate that these were not a part of the same dike, but rather two individual dikes which have come up through two separate openings. The end of the south dike tapers off to a point and the end of the upper dike on the north side seems to narrow down and pinch out. One small, nearly horizontal fault was observed in the discovery tunnel in the patented Pole Pick No. 1 mining claim. The quartz vein was dislocated about seven feet and the plane of faulting appears to be nearly horizontal. This fault probably represents merely a local break or slip and is not important. In nearly all of the tunnels passing through the serpentine formations, so-called walls or slips are frequent, which pitch and strike in various directions. The larger number of these, however, were apparently produced at the time of the serpentinization of the peridotite. Many of the fissure veins show secondary movement since their deposition, as may be seen in their grooved and slicken-sided walls.

GEOLOGICAL HISTORY.

The geological history of the Blewett Mining District is a part of the geological history of the Cascade mountains. The same diastrophic movements involved in the deformation of the Cascades during the various periods of its history, the changes in the relative positions of land and sea, the metamorphism produced by igneous intrusions, the deposition of sedimentary rocks in the large fresh water lake basins, and the final modification of the topographic features by the action of stream erosion, which has operated upon so tremendous a scale in developing the Cascades as a whole, have been the factors involved in producing the geological and topographical features in the area under discussion.

The formations in this region may be divided into two series which are separated by a pronounced unconformity. The older of these is represented by a bedrock complex, consisting of metamorphic and igneous rocks of Pre-Tertiary age. The younger of the two series is composed of non-metamorphosed sedimentary rocks together with igneous intrusive and extrusive rocks. The earliest records of the geologic history of this district must be sought for in the rocks of the Peshastin formation. The geological period during which this formation was deposited cannot be definitely determined by the evidence obtained within the area of this map, but it corresponds most closely to formations occuring in British Columbia, known as the Cache creek series, and to the Calaveras formation in the Sierra Nevada of California. In other portions of the Cascades, rocks similar to these occur. In British Columbia and California the formations most closely related to these are known to be Carboniferous, and based upon that evidence, the Peshastin formation provisionally may be assigned to the Carboniferous or older.

During Peshastin times, from all of the available evidence obtainable, this region was a part of the ocean or at least an arm of the ocean, and in it were accumulating conglomerates, sandstones, shales, and limestones. The pebbles forming the conglomerates were derived from the erosion of adjacent land masses, composed of earlier metamorphic rocks. In the deeper water far from the shore the shales and limestones were being laid down. During the time these were being deposited there appears to have been more or less crustal deformation, causing a part of the region to be slowly elevated and a part depressed. After a time volcanic activity became the important factor in the history of this region, and molten basic igneous rocks found their way to the surface, possibly from volcanic centers situated on some adjacent land area, or possible located upon islands which may have existed in the sea. At any rate, accumulations of volcanic ash and scoriae were deposited in the open waters, and then worked over by the waves, and intermixed with fragments of chert, greenstone, and slate, derived from the land masses along the shore. These were followed by outpourings of volcanic lava which picked up fragments of rocks composing the floor over which they were flowing, and carried them along in the current, giving rise to an aggregate of volcanic breccias. The precise order in which these disturbances took place cannot definitely be determined, but the conditions just described characterize this period of time and are the interpretation of facts gathered in the field. These materials constitute what are known as the Hawkins formation. Within this formation are irregular masses of diabase and gabbro porphyry, which indicate that a part of the lava at least may have reached the surface through fissures, and which upon cooling resulted in the formation of basic dikes. The two formations just described constitute a part of the Pre-Tertiary metamorphic complex and are separated by an unconformity, but neither the exact conditions nor the length of time intervening between them could be determined.

After the deposition of these two formations, deformational movements became a prominent feature in the history of the region, resulting in the uplift of the recently accumulated materials into the form of a mountain mass. The geographic conditions existing at this time cannot be definitely known because of the comparatively small area of these rocks exposed at the present surface. It seems probable that the region was undergoing erosion for a long time, and that the sediments were being carried off and deposited in some basin which is now deeply buried by later rocks. The next epoch was inaugurated by the intrusion of great plutonic masses of ultra-basic rocks. They were largely of the nature of peridotites and basic gabbros, the latter apparently being a differentiation product from the underlying magma. The time involved in the intrusion of these basic rocks must be conceived of as very long, during which there was not one single intrusive mass injected up into the earth's crust but rather a series of differentiations from a composite, basic magma deep below. We may consider first that those portions of the magma which were richest in iron and magnesia were drawn off from the underlying reservoir and injected into the earth's crust, and then to have solidified, forming a rock composed essentially of olivine and enstatite. Later more acid phases, richer in calcium and silica were drawn off from this same underlying magma and forced up into the already solidifying rock. The later intrusions were in the nature of basic gabbros and appear in the field as irregular shaped dikes, whose boundaries vary and gradually grade into peridotite. The age of this series of basic intrusions cannot definitely be stated. It is a known fact, however, that intrusions of peridotite were a characteristic feature of the Upper Jurassic near its close. Throughout the Sierra Nevada and the coast ranges of California* and Oregon they are known definitely to be Pre-Tertiary, hence the age of these intrusions may be provisionally assigned to the Jurassic. During Cretaceous time we have no evidence of sedimentation, and apparently none of volcanic activity, unless it be intrusions of granodiorite, which, however, may be of Jurassic age.

Subsequent to the time of the peridotite intrusion and prior to the deposition of the Eocene sandstones, this entire region was invaded from below by a great batholith of granodiorite, which is now represented by extensive outcrops in the vicinity of Mount Stuart and northward, and by numerous smaller dike-like apophyses cutting up into the peridotite and older metamorphic rocks. Accompanying these intrusions, there was much deformation and fissuring of the overlying rocks. From this slowly cooling, deepseated granodiorite magma, solutions under extremely high pressures and temperatures were gradually circulating upwards through the peridotite, and extracting calcium and iron from the calcium-ferromagnesium silicates, and in turn yielding up a part of its water to unite with the magnesium and the silica to form the hydrous magnesium silicate serpentine. This chemical alteration of the peridotite increased the volume of each individual crystal, causing much local crushing and shearing. It seems evident that these same solutions which were causing serpentinization also carried silica, gold, arsenic, iron, and sulphur, directly from the slowly solidifying granodiorite magma to the downward extending east-west fissures trending through what is now Culver gulch. Upon the release of pressure and the decrease in temperature, the mineral contents along with the silica and calcium carbonate were precipitated from the solution, forming the veins as we know them today in the deepest workings in Culver gulch. After these ore bodies were formed the region underwent extensive deformation and erosion until the beginning of the Eocene.

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*H. W. Turner, Geology of the Sierra Nevada; 17th Ann. Rept. U. S. Geological Survey, Pt. I, p. 549, 1896.

The Tertiary history of this region was inaugurated by intense deformation of the surface rocks, resulting in the formation of a great lake basin. The first material to accumulate in the form of deposits upon the floor of this lake consisted of a basal conglomerate, made up in some places of fine pebbles of serpentine, slate, and greenstone, and in other places of coarse bowlders of granodiorite. Succeeding these, as the lake enlarged and deepened, were sandstone, shale, and occasional carbonaceous beds. In the sands and muds were buried leaves fallen from trees, growing along the shores. These sediments are known as the Swauk formation. Following the deposition of this formation, volcanic activity again became an important geological factor, resulting in the intrusion of basic magmas through the numerous conduits leading up to the surface, and then spreading out as great basalt flows. The flows which are known as the Teanaway basalt do not occur within the limits of the area mapped, but are well represented only a short distance to the southwest. A little before the intrusion of the diabase dikes masses of gabbro were injected into the earth's crust, and apparently are genetically related to the dikes. After the outpouring of this material had ceased, this portion of the Cascades again underwent extensive deformation, resulting in the formation of a second large lake, in which accumulated the Roslyn formation of Upper Eocene age, but which did not extend as far northward as the Blewett district. During the remainder of the Miocene and Pliocene times extensive flows of lava were accumulating in the Cascade mountains, not far distant from Blewett, but as far as we have been able to determine, never covered this immediate region. During this long period of erosion, however, the region was reduced to a peneplain, and then at the close of the Pliocene or beginning of the Quaternary, the Cascades were again uplifted to at least 8,000 feet above sea level, by a series of complex deformational movements. The most prominent of these movements, and the one primarily affecting this district was the development of a long axial uplift or warp in the earth's crust trending southeast to northwest from Columbia river to Mount Stuart and known as the Wenatchee mountain uplift.

The physiographic processes involved during the Quaternary have already been described in the chapter dealing with the topographic development of the region. Briefly, they represent a gradual uplift of the Wenatchee mountain mass followed by the development of new drainage lines, the cutting of canyons by streams, the adjustment of the streams to differences in the character of rocks encountered and finally the modification of this newly developed topography by the advance and retreat of extensive glaciers. The very last events in this history are the geological and physiographic processes that are going on at the present time. Among these may be mentioned the accumulation in the valleys of the stream gravels, and alluvium, the former sometimes being gold bearing.

CHAPTER III.

ECONOMIC GEOLOGY.

HISTORY OF MINING.

Little is known of the earliest history of the Blewett Mining District. The first mining records are those of several prospectors who, upon returning from the Caribou and Frazer river districts, of British Columbia, and the Similkameen in northern Washington, wandered southward into the eastern foothills of the Cascades and while searching on Peshastin creek, in 1860, discovered rich placers. After working for a time the first prospectors migrated southward and the work was continued by those following them from the north. Very little information is at hand concerning these early pioneers. One of them, a negro, is said to have worked the gravels on Peshastin creek near the mouth of Negro creek, named for him, and to have taken out about $1,100. The discovery of the first quartz vein in this district is said to have been made by one of the United States soldiers in 1854, but it was not located.

About 1874 the first quartz claim was located by John Shafer near the head of Culver gulch and has since been known as the Culver claim. About the same time the Pole Pick, situated on the south side of Culver gulch, and the Hummingbird, were located by Samuel Culver. Shortly afterwards James Lockwood located the Bobtail, John Olden and Peter Wilder the Fraction, and John Olden and Samuel Culver the Little Culver.

While these locations were being made in Culver gulch, what was considered to be the same lead was found to extend eastward and upon it were located the Peshastin and Blackjack claims. Still farther east, on the east side of Peshastin creek, were located the Golden Chariot and Tiptop claims. To the west of Culver gulch, trending westward down to Negro creek, were located the Shafer, Vancouver and Seattle claims, by Marshall Blinn. Later these were sold to the Cascade Mining Company. In addition to these, many other locations were made on the Pole Pick and the North Star ledges, and others both to the north and to the south of the east-west mineralized zone.

In the very early days, Blewett was connected with the outside world by trail only, but in 1879 a wagon road was built from Cle Elum on the south, over the Wenatchee divide to Blewett. The ore bodies first opened up in the development of quartz mining were mainly those from the oxidized zone, which were free milling. Several arrastras were built for treating these ores, two of which have been in use until very recent years. Late in the seventies a six-stamp mill with one Frue vanner was erected and operated by water power. For about eight years this mill was run and the ores treated in it were obtained from the upper tunnels on Culver gulch. In 1891 a ten-stamp mill was erected by the Culver Mining Company, who sold it the following year to the Blewett Mining Company, who again resold it in 1896 to Thomas Johnson. In this mill were treated a large part of the ores from the Pole Pick, Tip Top, Blackjack, Peshastin, and other claims lying on the ridge between Culver and Culver Springs gulches. Shortly before the sale of this ten-stamp mill to Thomas Johnson, the Blewett Company erected the present twenty-stamp mill at the mouth of Culver gulch and began a systematic underground development of the property. From 1894 to 1897 the practice was made of leasing certain portions of the mines on a royalty basis, the result of which was the opening up and stoping out of the rich oxidized ores in the upper portion of the gulch. In 1896 the Warrior General Company was organized, which paid $35,000 to the Blewett Company for its property. Shortly afterward this company was reorganized and called the Chelan Mining and Milling Company. About this time extensive development of the Peshastin ore bodies was begun by driving a series of south cross-cuts from Culver gulch to the vein. Rich bodies of ore were encountered and for a time the Blewett district became very active. In 1905 this property, together with the La Rica, became the Washington

Meteor Company. During the last ten years the greater part of the work has consisted in the development and mining of the ores from the Meteor and Peshastin tunnels on the Peshastin claim and from No. 9 tunnel on the Culver claim. In recent years several properties have been patented and those which have not have confined themselves mainly to assessment work.

The placers in this district have been worked from time to time by individuals and in 1909 extensive plans were made to mine the gravel on Peshastin near the mouth of Negro creek by sluicing with water brought by flume from further up Negro creek. Because of poor management this did not prove a success and was abandoned.

During the summer of 1910 sixteen claims were located on a series of iron oxide outcroppings situated to the south of the Blewett district. Since these claims are not a part of this report, their description will not be undertaken.

TREATMENT OF THE ORES.

Up to the present time the ores of this camp have been considered as free milling. The greater part of these have been mined from the upper oxidized zone and consequently have been treated by crushing and amalgamation. The earliest method of treating these ores was by means of arrastras which were used intermittently up to within a very few years ago.

Two arrastras, situated near the mouth of Culver Springs gulch, are still in existence but are unused. Remnants of older ones may be seen on Peshastin creek and in Culver gulch. The best preserved one is owned by Mr. John Olden and is represented on Plate No. VB. The pit is twelve feet in diameter, three feet deep, and built of granite brought from outcrops not far away. The power is obtained by a large overshot water wheel, twenty-six feet in diameter, and run by a stream of water brought from the gulch by a flume and carried directly over the upper portion of the wheel. This operates a horizontal wheel to which granite bowlders weighing over one-half a ton are attached by chains. These are known as drag blocks and crush the ore to a fine powder. The arrastra is said to have crushed from one to two tons of ore per day.

The first stamp mill to operate in the state was erected on Peshastin creek and consisted of six stamps with one Frue vanner, and is said to have reduced eight tons of ore in twenty-four hours, and to have yielded $21 per ton from Culver ore in the first nine days run. After running for eight years this mill was shut down.

In 1880 a two-stamp Huntington mill was brought in from The Dalles, on the Columbia, and erected on Negro creek about two miles above its mouth. This mill was run for about two years and then stopped, never to resume. About fifty tons of base ore, assaying from $10 to $70 per ton, are said to have been reduced, but on account of the large amount of arsenopyrite, pyrite, and iron-copper sulphides it was impossible to save more than $4.50 per ton.

In 1891 the Culver Gold Mining Company erected a ten-stamp mill with four Woodbury concentrators on Peshastin creek near the mouth of Culver gulch and brought the ore from the head of that gulch to it by a cable tram. The following year this mill was sold to the Blewett Gold Mining Company and in 1896 was again sold to Thomas Johnson, who began milling the Pole Pick ore.

In 1892 the Blewett Company erected a twenty-stamp mill at the mouth of Culver gulch, allowing space for twenty more stamps. The equipment of this mill has been described by Professor Milnor Roberts in a previous report on the reduction plants in Washington* and will be inserted here. "The batteries consist of four sets of five stamps each, with Fraser and Chalmers automatic feeders, and double discharge, only single being used. 950-pound stamps, with chrome steel shoes and dies, drop 6½ inches at the rate of 90 per minute. The pulp is screened through diagonal slot screens, equivalent to 50 mesh, and falls on copper plates four feet wide and ten feet long, sloping 1½ inches per foot. The lower plates are silvered, 14 feet long,

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*1st Ann. Rep. Washington Geological Survey, p. 150, 1901.

4 feet wide, and falling two inches per foot. Four Union tables receive the pulp, after which the slimes pass over canvas tables with a three-inch fall. The canvas is swept four times in twenty-four hours, and the fines are saved in settling boxes. Under former management, the tailings carried values of several dollars, which ran into the creek. Outside parties becoming aware of this, built a small cyanide plant with two tanks, having a capacity of about ten tons per day, and thereby recovered a considerable amount of fine gold. The plant is no longer in use.

Wood is burned under two boilers (4 by 12 feet, used alternately), which furnish steam for a Corliss engine of 50 h. p. A flume 500 feet long brings water from the creek to a tank set 20 feet above the level of the stamp battery. A Hallidie aerial tramway with buckets holding 250 pounds each, carries the ore from the mine 4,000 feet distant and dumps it into two receiving bins of 400 tons capacity. The usual system prevails in regard to the different floors of the mill, the order here being crusher, feeding bin, battery, and concentrating floors." During the year of 1896 this mill is said to have reduced 2,469 tons of ore from the Culver claim, which assayed $12.62 a ton, and in addition to this 473 tons of customs ore; the total product of ore in bullion for the company in the year 1896 being $60,000.

In the summer of 1896, a small cyanide plant with two tanks and having a capacity of about ten tons per day, was erected near the twenty-stamp mill, for the purpose of treating the tailings. It had been found that the arsenic in the ore prevented the quicksilver on the plates from catching the gold and consequently dams were built to catch the slimes. 600 tons of tailings, assaying from $3.00 to $30.00 a ton in gold were accumulated, from which 70 to 75% of the gold was extracted by the cyanide process. Later this was closed until the summer of 1910, when the tailings were again run through by the Blewett Mining and Leasing Company.

During the summer of 1910 assays were taken on the iron stained serpentine rock on the south side of Culver gulch, just above the mill, and values reported sufficiently high to allow profitable mining. Chemical tests were made upon these ores with the result that it was deemed best to treat them directly by the cyanide process. Consequently the mill was dismantled, the concentrating tables taken out and three cyanide tanks of thirty-five tons capacity installed. At the present time it is impossible to determine what success was encountered.

In the summer of 1907 a six-stamp mill, with amalgamating plates, was erected in Culver gulch about one-third mile west of Blewett, by the Golden Eagle Mining and Milling Company. This mill is run by a 25 h. p. Fairbanks-Morse engine. Altogether about 100 tons of ore from the North Star and Golden Eagle claims have been reduced, yielding returns of $5 per ton. The mill was run during the month of July in 1910.

PRODUCTION.

Statistics of the total output of metals from this district are lacking. Gold and silver both occur, but the gold far exceeds in importance that of any other metal. The total production, including both placer and quartz, from 1870 to 1901, has been estimated at $1,500,000 and the greater part of this came from the mines in Culver gulch. From 1901 to 1910 it was estimated that these mines produced about $200,000 in bullion, making the total production of gold to the year 1910 about $1,700,000. According to General J. D. McIntire, who had charge of the management of the La Rica Mining Company's property at Blewett from 1900 to 1905, the ore values varied much but ranged from $3 to $10 per ton, and occasionally rich ore shoots averaged as high as $10,000 per ton.

DISTRIBUTION OF THE ORE BODIES.

The larger proportion of the ore bodies included within the Blewett Mining District occupy a belt approximately three miles in length and one mile in width, extending in a general east-west direction. This belt begins on the east side of Peshastin creek, on the slopes of Windmill point, crosses that creek at the town of Blewett and from there extends up Culver gulch, across the divide and down into Negro creek. Small isolated veins occur throughout the entire district but those which have proven commercially productive up to the present time are confined to the belt just mentioned. The richest ore bodies within this belt have been found in Culver gulch.

CHARACTER OF THE ORE BODIES.

The ore bodies occur in a series of irregular shaped but well defined fissure veins, situated chiefly in the serpentine rock. The vein material consists of quartz, calcite, and talc, carrying gold, arsenic, iron, sulphur, and a very small amount of silver, lead, and copper. In the upper or oxidized zone the gold occurs in the free state in the rusty, crumbly, decomposed iron-stained quartz, often containing much talc, especially along the hanging and foot walls. Occasionally great masses of unaltered quartz are intermixed but generally show numerous fracture zones filled with a coating of yellow iron oxide. In the deeper workings the vein material is more characteristically composed of calcite with quartz heavily impregnated with arsenopyrite and pyrite, carrying gold that ranges in value from one dollar to several thousand dollars per ton. In some of the richer pockets in the lower workings, large flakes and wire-like pieces of gold may be clearly seen with the naked eye. Many of the richest specimens occur in talc along the wall rock.

STRIKE. The predominant strike of the quartz veins in Culver gulch is approximately north 75° west. About half way between Culver gulch and Peshastin creek the entire series of veins swings more decidedly to the southeast.

PITCH. Three parallel veins occupy the fissures in Culver gulch. These are known as the Peshastin lead, the Pole Pick lead, and the North Star or Phoenix lead. The Peshastin, the most northerly of the three, and the one on which the largest amount of development work has been done, pitches predominately to the south at an angle of about 75°. In many places it is nearly vertical, but observations taken along the lateral extent of the vein, from the highest to the lowest workings, show that the southerly dip prevails. The Pole Pick or middle of these veins, near the surface at least, pitches to the north at an angle of about 70° but from observations made in some of the lowest workings there is reason to believe that the prevailing dip is nearly vertical and that the northerly dip near the surface is a part of the irregular curving in the downward extending fissure. The North Star or southern of these leads has been opened at only a few points and those are near the surface, hence no general deduction can be drawn as to the probable direction of the downward pitch. Small veins of no lateral or downward extent which have been worked in other parts of the district in general have an east to west strike but represent no prevailing series of mineral filled fissures.

SHAPE. The veins vary in width both along their lateral extent and in their downward pitch. Their shape and size is dependent mainly upon the original character of the fissure prior to mineralization. It is assumed that three predominant fissure openings were formed and that later sufficient pressure was exerted upon them to cause the walls in some places to meet, thus resulting in a plane of fissuring containing a large number of lens-like cavities which later were filled by mineral solutions. These irregular-shaped lens-like pockets are known as ore shoots and have been the source of the richer ores mined in this district. They vary in width from three to sixteen feet, in horizontal extent from 100 to 600 feet, and in vertical range from 20 to 200 feet. The vein material between these ore shoots generally consists of quartz seams or a mixture of quartz and calcite, carrying low grade ores and ranging in width from two or three feet to two or three inches. Very often these veins pinch out entirely, simply leaving the walls in contact with each other. Occasionally these barren zones are represented by a network of disconnected stringers of quartz and calcite with no well defined wall. Examples of these occur in the Meteor and Peshastin tunnels, in No. 9 tunnel, and in the various openings extending up to the head of Culver gulch, where the big summit pocket occurs. The ores in the summit pocket were mainly oxidized quartz and owe their richness to downward leachment. These old workings are inaccessible, but are said to have pinched out 200 feet below the surface. From their general character they may be regarded as the lower portion of an ore shoot, the upper portion of which had been removed by erosion earlier in Quaternary time. During all of Tertiary time, while this region had been undergoing extensive erosion, it seems probable that several thousand feet of overlying rock had been removed and that the upward extension of the vein originally existed in this upper belt. The deepest workings at the present time are on the level of Peshastin creek and while no definite data have been obtained by drilling, there is every reason to believe that the ore bodies will maintain the same general character and mode of appearance that they do in the lower workings in Culver gulch. No free milling oxidized ore may be expected, but arsenopyrite, and pyrite, along with quartz, calcite, and talc may be expected to carry the gold deposits.

Faulting does not play an important part in the displacement of the ore bodies. In many places the veins show the result of local movement along the zone of fissuring. These have occurred since the deposition of the ore, and are represented by smooth slicken-sided surfaces, more or less grooved and parallel to the direction of movement. Where this occurs the wall rock and vein have been ground up, resulting in a clay-like gouge material which is often filled with talc. These zones commonly represent channels for downward percolating water.

INFLUENCES OF COUNTRY ROCK ON THE ORES.

The ore bodies are found in the serpentine and to a lesser extent in the slates and quartzites of the Peshastin formation, and in the volcanic breccias and tuffs of the Hawkins formation. In the rocks belonging to the latter two formations the veins are more regular in character, but when they pass over into the serpentine they conform pretty closely to the conditions just described. Considering the main line of fissuring, extending through Culver gulch, the westernmost portions of the vein lie in the Hawkins formation and when traced easterly towards the serpentine contact, near the head of the gulch, they appear to widen out and split into parallel connecting fissures. When traced easterly beyond Peshastin creek, they again pass into the

Hawkins and may be seen in the workings of the Tip Top mine, up towards Windmill point.

The character of the ore varies with the country rock. Where the veins occur in the Hawkins breccia there is a larger percentage of quartz forming the gangue material. In the serpentine, calcite plays a more important part. No very deep workings have been developed upon the vein in the Hawkins formation and consequently our information in regard to the character of the ore in depth is meagre. On the lower Blinn tunnel on Negro creek the ore is said to have been quartz with some calcite, containing arsenopyrite, pyrite, and chalcopyrite. The property was inaccessible at the time and only a few specimens of the ore said to have been taken from this tunnel were seen.

ALTERATION OF COUNTRY ROCK.

Along the general trend of the veins in this district the country rock has been considerably altered. On the surface it appears as a long, reddish-yellow belt, due to the staining of the wall rock by iron oxide. Below the surface this altered condition is not so prominent and the walls are found to be composed of serpentine, more or less impregnated with iron sulphides and seams of calcite. These belts vary in width from 10 feet to over 100 feet and are locally known by the miners as porphyry dikes. In many places they are porphyritic, but they represent in such cases the less serpentinized phases of the peridotite. A chemical analysis has been made of a specimen from one of the most typical outcrops forming the north wall of the North Star vein, on the south side of Culver gulch, at the North Star mine tunnel, and is inserted below.

MINERALOGY.

In this district the ores may be divided into free milling, oxidized quartz veins near the surface, and quartz-calcite veins carrying arsenopyrite and pyrite, with gold at depth. The vein material in the oxidized zone consists of white, barren, compact quartz, more or less fractured, broken, and stained with iron oxide, and often showing small flakes of gold. In the lower workings the gangue material is commonly composed of quartz or calcite, banded with chloritic material, and with talc occurring on the vein walls. The gangue is thoroughly impregnated with pyrite, arsenopyrite, and occasional crystals of galena. In the talc free gold is common. On Negro creek chalcopyrite also occurs in the veins whose walls are made up of the breccias of the Hawkins formation. When serpentine forms the walls, as it does in Culver gulch, it is usually heavily impregnated with pyrite and yields a small amount of gold. A chemical analysis of this rock was made from a specimen collected from the north wall of the North Star vein, at the face of the upper North Star tunnel, and is here inserted. (Analysis made by M. C. Taylor.)

No. 1107.

SiO_2	31.88%
Al_2O_3	trace
Fe_2O_3	5.81
FeO	6.21
MgO	26.42
CaO	6.84
Na_2O K_2O	0.83
H_2O above 110°	0.82
CO_2	22.02
Total	100.83

Quartz. Quartz is the most prominent vein material, and generally occurs in a milky white form with occasional bands of pyrite and arsenopyrite running through it, or disseminated through it in small isolated crystals. Free gold occasionally may be seen in small flakes within it. In the oxidized zone it is generally heavily stained with iron and sometimes breaks down into a soft crumbly mass.

Calcite. Next to quartz calcite is the most prominent gangue mineral. It occurs in greater abundance in the lower workings than in the upper, and has impregnated through it pyrite, arsenopyrite, and free gold.

Limonite. This mineral occurs in the upper workings as a coating on quartz and serpentine, and represents the oxidized iron sulphide.

Magnetite. This mineral, scattered through the peridotite and gabbro masses, occurs along the contact between the peridotite and Swauk sandstone just south of the district and north of Shaser creek as the cementing material of a basal Swauk conglomerate, and has been derived from the peridotite mass.

COPPER. Native copper is very rare in this district. One small hand specimen taken from a diabase dike at the head of Culver gulch showed a few small particles clinging to it. It is said to have been obtained in small amounts in the lower workings on the Blinn property.

PYRITE. This mineral is the most common sulphide. It occurs sparsely disseminated through the Peshastin slates, through the breccias of the Hawkins formation, and in the serpentine especially near the mineral veins. In the veins proper it occurs as crystals, as well as in the massive form. Occasionally it forms bands in the quartz and calcite. The talc on the hanging and foot walls is heavily impregnated with cubes of pyrite ranging in size from six inches in diameter to those which are microscopic.

ARSENOPYRITE. Next to pyrite, arsenopyrite is the most common sulphide, especially in the lower workings. It occurs in small crystals as well as massive and is directly associated with pyrite and with stibnite. It is generally associated with the ores in the Meteor and Peshastin tunnels, where some of the richer gold ores have been extracted.

CHALCOPYRITE. Chalcopyrite is sometimes found, along with pyrite and arsenopyrite, in the veins on the Blinn property. It is generally associated, when present in any quantity, with the gabbro masses.

GALENA. This mineral is not commonly found. It occasionally occurs in very small cubes, along with arsenopyrite and pyrite, in the veins in Culver gulch.

STIBNITE. This mineral has been found, along with arsenopyrite, in the workings in the Peshastin tunnel but is not characteristic of the district.

MALACHITE. Malachite occurs in the oxidized zone in the gabbro area, in a small shaft on the ridge leading westward from the United States mineral monument at the head of Culver Springs gulch. It occurs as a coating extending through the gabbro mass but has not been found in sufficient quantities to pay.

CINNABAR. Mercury sulphide is found at intervals in the serpentine rocks west of the Blewett area, but within this district has been reported only in the small saddle at the head of King creek. A very narrow seam, less than .1 inch in width was found cutting through the serpentine in an east-west direction, but could not be traced over 20 feet.

GOLD. Gold occurs native in both the oxidized zone and in the lowest workings yet encountered. As a rule it is very fine, so that it cannot be detected with the unaided eye, yet may be seen by pulverizing the ore and panning it. Sometimes large flakes may be seen extending through the quartz, calcite, and talc gangue matter. Some exceptionally rich specimens of talc containing stringers and films of native gold were taken from the rich ore shoots on the Peshastin claim. The placer gold is generally fine. The largest nuggets are said to have had a value of about $9 each.

GENESIS OF THE ORES.

All of the veins in this district are confined exclusively to the Pre-Tertiary formations. They occur mainly in the peridotite and serpentine rocks but extend also into the Peshastin and Hawkins formations. No evidences of ore deposition were found in the lower Eocene sandstones. During the period when the lower Peshastin and Hawkins formations were being deposited the region was undergoing much deformation and finally was elevated above the sea level. Later came a series of intrusions of basic igneous magmas in the nature of peridotite. These intrusions caught great blocks of the overlying rock and engulfed them into its mass. Then followed a period of erosion and later came intrusions from a great underlying batholith of granodiorite, a large part of which is now exposed at the surface in the region about Mount Stuart. Extending up through the serpentine and the other metamorphic rocks are long dike-like apophyses of this same granodiorite. These facts indicate that not very far below the present surface these dikes coalesce and become a part of the underlying batholith. At some time after the intrusion of the peridotite and prior to the deposition of the Swauk sandstones, these peridotite masses were altered to serpentine by processes which were hydrothermal in nature. This process of alteration involves the hydration of the iron magnesium silicates which are the component minerals of the peridotite and thereby causing an increase in volume of the original rock. This increase in volume exerted differential pressure throughout the mass causing many zones of shearing and minor faulting, the result of which was, the development of irregular curved and slicken-sided surfaces. While there is no direct evidence that the granodiorites have assisted in the serpentinization of the peridotites, yet it may be inferred that the heated waters which were gradually being driven off from the slowly cooling underlying magma were responsible.

It has been suggested that the ore bodies may have been derived from the solutions genetically associated with the intrusions of the Eocene diabasic dikes, because of the direct origin of the ores in the Swauk mining district from these dikes. The observations made at the contact between the diabase dikes and the Culver vein in Culver gulch indicate that the dike is younger than the vein and, if this be true, the period of ore deposition in this district must have occurred at the time or just after the intrusion of the granodiorite and prior to the intrusion of the diabase dikes. If this theory is correct there is a suggestion that the same heated solutions which were derived from the granodiorite and yielded the water necessary for the serpentization of the peridotite may have also acted as the mineral bearing solutions, which upon reaching the more prominent fractures and fissures deposited the ores. It would seem very probable that much extensive faulting would occur accompanying the deformation produced by the intrusion of the granodiorite magma and that these faults would extend downwards perhaps even to the magma itself. Considering that at this same time the peridotite was undergoing serpentinization, one would expect that any open fissures which might exist would become partially closed due to the pressure exerted by the hydration and increase in volume of the peridotite resulting in a fissure with the walls in contact but leaving lens-like openings more or less connected throughout the original plane of faulting. Under these conditions the heated solutions emanating from the granodiorit magma below and heavily charged with their mineral content would, after slowly permeating through the peridotite mas find their way to these openings and then slowly circulate up wards toward the surface and under reduced pressures and lowering of the temperature, the mineral content along with t silica would tend to crystallize out. The first precipitati would occur as an incrustation along the walls of the cavities a the fissures and as more and more material was brought by upward circulating solutions, continued precipitation would timately fill all of the open spaces in the fissures and consti what we know as the vein. In many cases the fissures mi tend to split and the two portions extend along parallel to e other, separated by blocks or masses of peridotite, and then mately converge, and the filling of these separated portio the fissure with vein material derived from the circulating tion would produce what are known as "horses." In the vic where the parallel fissures re-unite, and in the lenticular ca along the line of faulting, it would be possible for the circula solutions to interact, producing physical and chemical cha more favorable to the precipitation of the mineral content in the extremely narrow portions of the fissure where the approach each other. Considering the vast extent of this derlying batholith of granodiorite and the long time neces for it to cool it would be possible for mineral bearing solut to be given off and to circulate upwards long after the sol cation of those portions nearest the surface.

Throughout the whole region involved in this report w the peridotite or serpentine outcrops at the surface there numerous dikes of this granodiorite ranging all the way fr

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few feet to several hundred feet in width and varying in texture from that closely approaching an andesite porphyry to that of a diorite porphyry. In some of the larger areas they become almost plutonic in character. In several places in the upper portion of Culver Springs gulch some of the extremely narrow dikes almost grade into quartzitic veins. A careful study was made at the contact of these dikes with the serpentine and in many cases the latter was of the bright green schistose variety or dark green to black, resembling obsidian or broken glass. Specimens of serpentine collected within three or four feet of the contact are often heavily stained with iron oxide and contain secondary silica in the form of opal, along with numerous very fine disseminated crystals of pyrite. An assay made of one of these samples taken from the granite-serpentine contact on the hillside just below King creek yielded a return of .04 of an ounce in gold.

The only other rocks available that might be considered as the source of the vein materials are the diabase dikes or the gabbro intrusions. If the conclusion be correct that the diabase dikes were intruded at a later time than the formation of the ore bodies and this conclusion seems pretty well established from their contact relations in the face of No. 5½ tunnel, then the diabase may be eliminated as a possible source. The gabbro intrusives are probably closely associated if not contemporaneous with the diabase. They were intruded as sills into the Swauk formation, as may be observed north of Blewett in Camas land which is outside the area of this map, and are apparently cut by at least one diabase dike on the ridge forming the divide between Negro and Ingalls creeks. The only ores found associated with these gabbro masses are low grade copper sulphides which do not occur in well defined veins but rather as scattered impregnations in the gabbro mass.

Thus there does not seem to be any well grounded evidence for considering the gabbros as the source of the gold ores in the Blewett district. The only conclusion to be drawn is that the mineral bearing solutions must have been derived from the granodiorite. The actual occurrence of the ore bodies in this district, the size, shape, and relations of the veins to the country rock, conform very closely to the conditions just outlined.

While no positive statement to this effect can be made, there is a strong suggestion that the gold bearing veins in the Blewett mining district have been derived from heated waters given off from the underlying, slowly cooling granodiorite magma. After circulating through the peridotite masses and having helped to produce the serpentinization of the peridotite, they found their way to the partially deformed and squeezed fissure zones and there under gradually reduced temperatures and pressures precipitated their mineral content. When this process of mineralization was finished there is good reason to suspect that this entire region was still covered over by a tremendous thickness of Pre-Tertiary sedimentary and volcanic rocks, which were extensively metamorphosed by the intrusions just discussed.

From this time on to the beginning of the Eocene the region is supposed to have undergone extensive deformation and erosion, so that a large part of the covering was removed and redeposited as sandstone and shale in the early Eocene fresh water lake beds. Then owing to deformational movements of this portion of the Cascades the region itself was submerged until it became a part of the floor of an early lake and upon it accumulated a thick deposit of sedimentary rocks which in turn were again removed by erosion during a more recent uplift of the region. Hence a large part of the rock originally containing mineral veins has been worn away and a part at least has accumulated as placer quartz and gold in the Swauk formation and in the later Quaternary gravels.

PLACER DEPOSITS.

The placers were the first deposits to be worked in this district and more or less attention has been paid to them ever since. They are confined to the stream valleys, and chiefly to Peshastin and Negro creeks. The richest and most extensive deposits occur north of Blewett on the Peshastin, near the mouth of Negro creek. These gravels were originally derived from the upward extension of the present quartz veins in this district, by the erosive action of the smaller gulches and creeks emptying into Peshastin and Negro creeks. These old channels occupy in a general way the trend of the present valleys but do not always conform to the present winding of these streams. The downward cutting of the streams initiated by the upward movement of the mountain mass carried onwards the rounded pebbles of quartz and country rock and deposited them where they are now found. The placer gravels vary in thickness and character and may be divided into two groups, one representing the gravels as they were originally deposited, and the second those that have been worked over by the present streams. The former comprise the bench gravels and a part of those lying next to the bed-rock; the latter, those gravels on a general level of the present creek beds. In general the older gravels contain the richest deposits of gold. Through these the gold is pretty evenly distributed, but is richest close to bed-rock. Where the bed-rock is composed of slate many crevices and water-worn pot holes contain exceptionally rich deposits of gold. An instance of this may be cited on Peshastin creek, near the mouth of Negro creek, where nuggets having a value of $6.75 are said to have been taken out. On Negro creek, for a distance of two miles above its mouth, wide bars occur which have been worked by sluicing. The average depth of these bars is about five feet and the average pay ranges from ten cents to $1.25 per cubic yard.

CHAPTER IV.

DETAILED DESCRIPTION OF THE MINES.

INTRODUCTION.

In the examination of the mine properties in this district, all of the accessible underground workings were visited, and the ore bodies carefully studied, as well as the character of the wall rock. Unfortunately many of the old workings had caved in and were entirely inaccessible. In such cases it has been necessary to rely upon the older mine surveys and upon such statements as could be obtained from the older mining men who had worked there and whose statements seemed most authentic. Some of the properties have been extensively developed and others are represented by merely a few feet of surface tunnels. In all there are at the present time about forty claims in the district, owned by fourteen different companies or individuals. Eight of these claims are patented. In addition to these a large number of claims have been abandoned. In describing each of the individual properties the more salient features will be presented in the following order: the geographical location; the history of the development; the underground workings and production; and the economic geology. The latter will include a description of the country rock, the form, distribution, and chartacter of the ledges, and their relation to the country rock.

THE WASHINGTON METEOR MINING COMPANY.

Location. This property consists of seven claims located in Culver gulch and extending from Peshastin creek on the east to its head near the United States mineral monument on the west. The claims are the Culver, Bobtail, Hummingbird, Sandell, Peshastin, Blackjack, and Keynote. The total amount of underground development on this property consists of over 7,000 feet of tunnel in addition to upraises, shafts, and open cuts.

The developments have been made mainly on one vein, which will be known as the Peshastin and which is the same as the Blackjack, Culver, and Hummingbird leads. In addition to the underground development, several miles of aerial tramway, a twenty-stamp mill, cyanide plant, and assay shop have been installed.

HISTORY. The Culver claim was discovered and located by John Shafer in 1874. The Hummingbird by Samuel Culver, the Bobtail by James Lockwood, and the Sandell by John Olden and Peter Wilder, were all located in the same year. A little later all of these claims were bought by James Lockwood and his son, E. W. Lockwood, and H. N. Cooper, who erected a six-stamp mill and operated the property for eight years. It was then sold to Thomas Johnson and again re-sold in 1891 to the Culver Gold Mining Company. A ten-stamp mill was then erected and was connected with the mines by a cable tramway. In 1892 this company was bought by the Blewett Gold Mining Company, who erected the present twenty-stamp mill, situated at the mouth of Culver gulch, and which has been described under the heading, "Treatment of Ores." A steam sawmill was built about three miles above Blewett to supply timber necessary for carrying on mining and milling operations. All of the machinery used in this mill was brought in over the road from Cle Elum. Until 1894 the mill and mine were operated by the same company, but after that year the practice was made of leasing different portions of the mine while the company still operated the mill and charged a royalty on the output, as well as the cost of milling. It was estimated that about sixty men were thus employed continuously for three or four years. About this time it was found that a large part of the gold was not caught on the amalgamating plates, due to the presence of arsenic, but ran off in the slimes. Consequently a cyanide plant was erected under the direction of A. J. Morse, for Rosenberg and Company, one of the lessees, and 600 tons of tailings were treated, giving values ranging from $3 to $30 per ton.

In 1896 the Blewett Mining and Milling Company passed into the hands of the Warrior General Company, which, in turn, in the year 1901, was bought by the Chelan Mining and Milling Company. In the same year Mr. Thomas A. Parish, the owner of the Peshastin and Keynote claims, organized the La Rica Mining Company and later acquired the Blackjack property. Later both the La Rica and the Chelan companies were consolidated as the Washington Meteor Mining Company. This company has continued to operate to the present time. In 1910 the property was leased for a term of five years to a company composed largely of stockholders and known as the Blewett Mining and Leasing Company. During the past year they have taken out the amalgamating tables from the stamp mill and installed in their place cyanide tanks.

UNDERGROUND WORKINGS. The underground workings of this property may be best seen by referring to Plates VIII and IX. The oldest workings occur near the head of Culver gulch, in the vicinity of what is known as the Summit pocket, and are represented by the various underground workings associated with tunnels 1, 2, 3, and 4, on the west side of the big basaltic dike. The most easterly workings on this property are located on the Blackjack claim, and consist of a tunnel driven westerly on the vein at the level of Peshastin creek for a distance of 1,300 feet, together with shafts and upraises. Three thousand tons of ore are said to have been stoped out, yielding an average value in gold of $10 per ton. Several other similar openings have been made on the vein upon this same claim. Proceeding westward, the next developments are found in the Meteor tunnel, located on the Peshastin claim. This tunnel consists of a diagonal cross-cut to the vein and then a drift westward for about 700 feet. Several upraises were made which connect with the Peshastin tunnel.

The Peshastin tunnel is about eighty feet higher, and consists of a cross-cut tunnel extending from the center of Culver gulch southward for a distance of 300 feet, where it intersects the vein. Drifts have been run both to the east and to the west for a distance of over 1,000 feet, and an upraise driven to connect with the Sandell tunnel.

The Sandell tunnel is a cross-cut extending southward for 300 feet, where it cuts the main Peshastin lead 180 feet higher than the level of the Peshastin tunnel and consists of a series of drifts on the vein.

The Draw tunnel, whose portal is situated in Draw canyon, at an elevation of 120 feet above that of the Meteor tunnel, has been driven into the west directly on the vein, and is connected by upraises from the Meteor and Peshastin tunels below. Several large and very rich ore bodies have been worked from these tunnels.

The next tunnel to the west is the Hummingbird, which consists of a cross-cut from Culver gulch southward for a distance of 150 feet, where the same vein is intersected. Drifts have been run in on this for about 500 feet. Further up the canyon and to the west of this is the Bobtail tunnel, which has been driven directly on the vein. This is locally known as the Y tunnel. On the western end of the Bobtail claim, the tunnel known as No. 9 has been driven in zigzag fashion, resulting from failure to find definitely the position of the vein. As the work progressed this tunnel was extended on into the Culver claim and crossed the south side line of the Culver into the Pole Pick No. 2, at the northeast corner of that claim.

About 300 feet west from the mouth of No. 9 tunnel a cross-cut known as No. 8 tunnel has been driven northward a distance of 200 feet to the vein. At a point about twenty-five feet in No. 9 tunnel, back from the point where the tunnel crosses the side line of Culver claim into the Pole Pick claim, an upraise has been made on the vein for a distance of 266 feet to the Blewett tunnel. This tunnel is a cross-cut from the center of the gulch, northward to the vein and about 100 feet beyond and again reaches the surface by an easterly drift on the vein. At the point where the upraise from No. 9 tunnel reaches the Blewett tunnel a continuation of the upraise has been made up to No. 6 tunnel, which has been driven in, westerly, on the vein. Below No. 6 tunnel, a tunnel known as No. 6½ has been driven westerly on the vein which is connected by an upraise with No.

6, No. 6 is connected with No. 5½ and the latter with No. 5, both of which have been driven on the vein. No. 5½ extends to the diabase dike, where the vein has been cut in two by the intrusion. A large part of the ore from the level of No. 9 tunnel up to No. 5 has been stoped out and transferred to the stamp mill at the mouth of Culver gulch by a bucket tramway. A large part of this work was done by leases from 1894 to 1900.

GEOLOGICAL RELATIONS. The veins in this property represent an east to west zone of fissuring which has been filled with quartz, calcite, and talc, heavily impregnated with arsenopyrite and pyrite, and containing varying amounts of gold. The country rock is serpentine in various stages of alteration. In the vicinity of the veins, there are prominent reddish colored bands, due largely to staining with iron oxide, and containing many small seams of calcite. In places this grades into a greenish rock and has been known locally by the miners as porphyry, but which upon examination is found to be an altered phase of serpentine.

The general trend of this vein is north 75° west, with a very steep pitch to the south. The vein varies in width from a thin seam to sixteen feet. On the Peshastin claim two ore shoots were found known as the "Parish" and the "McCarty" shoots. These were worked mainly from the Peshastin tunnel but they extended down to the Meteor tunnel. They pinched out to a very narrow seam above the level of the Peshastin tunnel and also narrowed down both to the east and to the west along the general direction of the vein. The ore in these shoots was largely calcite and talc with some quartz, but rich in arsenopyrite and pyrite. Specimens exceedingly rich and containing free gold were common. The gold occurs in flakes and in wire-like form and it is especially noticeable in the talc. In the workings to the west of these ore shoots the veins become much narrower, and in some cases are very low grade. The walls in places are ill defined and hard to follow. Still farther west on the Hummingbird and Bobtail claims, they again widen out and rich ore has been obtained. In the upper workings, extending from No. 9 tunnel to the head of the gulch, in the Summit pocket, the ores were exceptionally rich, due largely to their lying in an enriched oxidized zone. Towards the head of the gulch, the main vein has a tendency to split and again coalesce. It is here that some of the richest ore ever taken out of the camp occurred. Some of this is said to have yielded $60,000 to the ton.

PRODUCTION OF THE MINE. No detailed records have been kept of the production of this mine but according to Gen. J. D. McIntire, who operated these properties for several years, the Washington Meteor Company together with those which preceded it have received approximately $1,200,000 in gold.

FUTURE OF THE MINE. Considering the general character of the ore bodies which have already been mined, the relation of these to the country rock, and the theories which have already been discussed relating to the origin of these ore bodies, the conclusion is drawn that lenses of rich ore, with intervening barren stretches of low grade ore, will extend throughout the entire east to west limits of the property, to a depth of at least 1,000 feet below the lowest workings, namely the Blackjack tunnel at the level of Peshastin creek. Whether this can be mined profitably or not depends upon whether the returns from the lenses of very rich ore will be greater than the cost of mining in the intervening stretches of low grade ore. If future operations are carried on intelligently and economically, they should be made to pay.

ALTA VISTA MINE.

(POLE PICK NO. 2 CLAIM.)

This property lies on the south side of Culver gulch about one mile west of Peshastin creek. It joins the Culver claim on the north and the Pole Pick No. 3 of the Cascade Mining Company's group on the west. On the east it is separated by a fraction from Pole Pick No. 1 of the Ellinor Mining Company. The position and underground workings of this claim may be referred to in Plates VIII and IX.

This claim was located in 1874 by John Earnest, and was later acquired by John Shoudy, but in 1906 was sold to Mr. Thomas A. Parish, who organized the Alta Vista Mining Company.

The development work consists approximately of 790 feet of underground tunnel, and several open cuts upon the surface. The largest tunnel is a continuation of No. 9 tunnel from the northeast corner of the claim westward for a distance of 292 feet. Ninety feet west from this northeast corner, a cross-cut has been driven southward for 200 feet, for the purpose of tapping the downward extension of the Pole Pick vein. On the Pole Pick No. 2 fraction just east of this claim, and about 350 feet in elevation above the level of No. 9 tunnel, three short tunnels have been driven westward on the vein for a distance of about 200 feet each. One hundred feet higher a fourth tunnel has been run on the vein for a distance of 100 feet. The long tunnel extending from the northeast corner westward has been driven on the vein and a raise has been run upward for a distance of thirty feet.

This vein consists of quartz, calcite, and talc, heavily impregnated with arsenopyrite and pyrite, and yields assays in gold ranging from $8 to $200. The vein varies in width from four feet to a mere stringer and has a general strike ranging from north 88° west to due east and west.

The south cross-cut extends 90 feet and cuts a well defined fissure zone with slicken-sided walls and is composed of crushed serpentine filled with a network of quartz and calcite vein material containing a large amount of arsenopyrite and pyrite and yielding assays ranging from 0.04 to 1.6 ounces to the ton. About ten feet north of this zone a similar narrow stringer of calcite parallel to the main zone gave assays of $27 per ton. The width of this mineralized fissure zone averages four feet with a nearly vertical pitch and a strike of north 78° east. The cross-cut has been driven ten feet further through a hard flinty rock composed of serpentine thoroughly impregnated with almost colorless, barren quartz.

The three short tunnels on the Pole Pick No. 2 fraction show a more or less oxidized quartz vein with occasional crystals of pyrite scattered through it cutting up through the serpentine, and having a general strike of north 80° west. The pitch varies from vertical to 75° to the north. The vein is much broken, due to the close proximity of the diabase dike. This dike strikes southwest to northeast and in the vicinity of the veins thins and narrows and has apparently cut the vein off from its connection with the Ellinor Pole Pick No. 1. The Gold Pan-Pole Pick tunnel above the three tunnels on the fraction shows a quartz vein four feet wide and in places is composed of crumbly, iron-stained broken material. One hundred feet from the mouth of the tunnel much calcite enters into the vein. Eight general assays were taken from the vein in this tunnel and none of them gave values lower than $27 per ton.

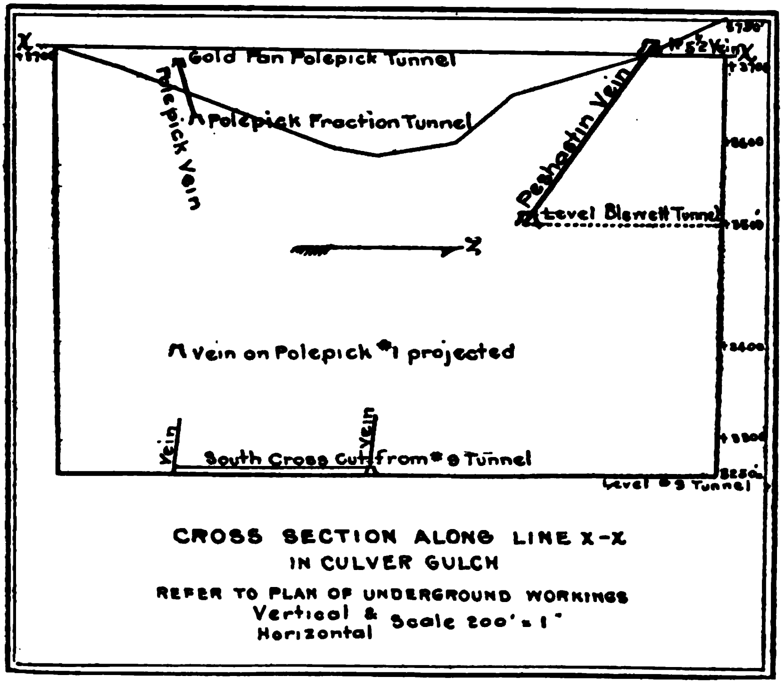


Fig. 1. Cross section to show relation of Polepick and Peshastin veins.

POLE PICK NO. 1 MINE.

The Pole Pick No. 1 claim lies on the south side of Culver gulch, about one-half mile west of Blewett and is owned by the Ellinor Mining Company. This claim was located in 1883 by Samuel Culver. Later this was bought by Thomas Johnson and on October 16th, 1901, was sold to Chicago parties who obtained a United States patent and now hold it under the name of the Ellinor Mining Company. The development work on this property consists of two cross-cut tunnels driven from Culver gulch, southward to the Pole Pick vein. One of these tunnels is 200 feet long and in it an upraise has been driven on the vein for a distance of 147 feet and at the 100-foot level a drift has been driven west for a distance of 100 feet and from this drift an upraise has been made to the surface. In these workings a larger part of the ore has been stoped out and treated in the ten-stamp mill bought from the Blewett Mining Company. Assays made on this at the time the ore was extracted are said to have averaged from $10 to $132 in free gold. The vein is mainly hard, massive, milky quartz, ranging in width from one to four feet. The trend of this vein is approximately north 80° west and the pitch 80° to the north. The country rock is entirely serpentine. In 1901 it was estimated that this mine had produced about 8,000 tons of ore, having a value of $70,000. Near the surface the Pole Pick lead apparently consists of three veins converging in depth. To the east of this claim the continuation of these veins is hard to trace although certain isolated outcrops may represent them, extending through the Rising Sun claim to the mouth of Culver Springs gulch.

BLINN MINE.

This mine is situated on the western slope of Negro creek and extends from the United States mineral monument at the head of Culver gulch westward to and across Negro creek. This property consists of five claims known as: The Shafer, Olympia, Pole Pick No. 3, Seattle, and Vancouver. They are all patented and owned by the Cascade Mining Company. They were first located in 1878 by Marshall Blinn. In 1889 this property was bonded to Edward Blewett but later passed back into the hands of the Cascade Mining Company.

The development work on this property consists of one long tunnel driven eastward on the vein from Negro creek into the hill, and about 1,000 feet of shorter tunnels distributed over the five claims. On the Shafer claim, near the head of Culver gulch, a tunnel was driven on the vein for the purpose of tracing the ledge into the Peshastin vein. This ledge was found to split up into several smaller ones and become a part of what is known as the Summit pocket, near the mineral monument. In 1880 a two-stamp Huntington mill was erected on Negro creek on the Seattle claim, but on account of the high percentage of sulphides of iron and copper in the ore only a small amount of the gold could be saved. The vein running through these properties has a trend of north 75° west, with a nearly vertical dip and is the western continuation of the Peshastin vein.

On the Olympia claim the country rock is partly serpentine, but the western half of the property, including the Seattle and Vancouver claims, is composed of breccias belonging to the Hawkins formation. The vein varies in thickness from one to five feet and consists mainly of quartz and subordinate amounts of calcite.

NORTH STAR MINE.

This mine is located on the south side and near the upper end of Culver gulch, and is owned by the Golden Eagle Mining & Milling Company. It was first located on October 1st, 1882, as the Golden Phoenix, by William Donnahue, and later sold to Patrick Henry. It joins the Pole Pick No. 1 patented claim on the south. In 1906 it was leased to the Golden Eagle Company, who in 1908 erected a six-stamp mill, with Wilfly tables, etc. It is run by a 25 h. p. Fairbanks-Morse engine. This mill is situated in Culver gulch about one-fourth mile west of Peshastin creek.

While still owned by William Donnahue, a vein of brown oxidized quartz was tapped at a depth of 100 feet by cross-cutting

125 feet. Then levels 100 feet long at intervals of twenty-five feet were run and from these ore was stoped up to the surface. It is reported that 1,000 tons of ore were taken out and treated at the Blewett mill, yielding average returns of $20 per ton in gold. Later, in 1907-08, two tunnels were driven on the vein by Mr. Jack McCarty, the lower one for a distance of 62 feet, and the upper 258 feet. In the lower tunnel the vein is two feet wide and strikes north 70° west, with a vertical pitch. In the upper tunnel, which is about forty feet higher in elevation than the lower tunnel, the strike is north 73° west, and the pitch vertical. At the face of the upper tunnel an upraise has been made on the vein for twenty feet.

The ore is quartz, intermixed with calcite and talc, and heavily mineralized with pyrite. Only a very small amount of arsenopyrite was observed. The vein varies in width from one to eight feet and is enclosed within serpentine walls. On the surface these are stained red by iron oxide and are referred to by the miners as red porphyry. An analysis of this rock has been inserted in the chapter on ore deposits, on page 76. Assays taken at various intervals across this vein range from $1 to $15 per ton, but higher values are said to have been obtained from the Donnahue opening on the same vein during the early days of mining. This is a distinct fissure vein, approximately parallel to the Peshastin and may be assumed to have been formed at the same time and in the same manner. Future development may be expected to show irregular lenses of high grade ore with barren intervals between, lying in the plane of fissuring.

GOLDEN EAGLE MINE.

This claim is situated on the north side of Culver gulch, about one-half mile above its junction with Peshastin creek. It was located in 1902 and is owned by Jack McCarty of Blewett. The development work consists of an upper and lower tunnel. (Diagram on Plate X.) The upper tunnel has been run as a cross-cut in a direction north 25° west, for a distance of 110 feet, to the vein, and from the face a drift has been run on the vein westward for a distance of sixty-three feet. Four feet from the main cross-cut, on the drift, an upraise has been made on the vein to the surface. The lower tunnel represents 650 feet of work and is mainly a cross-cut extending due north with several branches.

The vein is composed of quartz, calcite, and talc, impregnated with iron pyrite, and having a thickness varying from one to three feet. It trends in a direction north 80° east, and pitches about 80° north. The country rock is mainly serpentine, containing isolated blocks of quartzite from the Peshastin formation. When traced to the westward and eastward it is difficult to find any continuation of the lead. The evidence obtained in the field indicates that as the vein extends westward it passes into the Hawkins breccia and becomes narrow and irregular but continues on as a part of the Golden Guinea vein on the Negro creek slope. Two assays taken across the vein from the upper tunnel, near the upraise, gave results of $3.75 and $4.10 per ton.

TIP TOP MINE.

This property consists of two claims, the Tip Top, and Golden Cherry, and is owned by the Tip Top Mining Company. These claims are situated on the east side of Peshastin creek and extend from the town of Blewett eastward toward Windmill point.

The Tip Top claim was located by John Sumners in 1880. It was first worked by the Tip Top Mining Company. A shaft on the ledge was sunk for a distance of seventy-five feet and two cross-cut tunnels 380 and 400 feet in length were driven into the vein. The ore was stoped out to the surface and run through an arrastra. This oxidized ore is said to have given an average return of $40 per ton. In 1888 it was abandoned and again re-located in 1889 by T. J. Vinton, who in 1895 leased it to several parties, who took out ore and treated it at the Blewett mill. All of the tunnels on this property were inaccessible at the time of examination and most of the information was obtained from miners who had previously worked there.

The vein is said to have averaged two and one-half feet in width, and to have had a general east-west strike, with a pitch to the north. The country rock is partly serpentine and partly breccias of the Hawkins formation.

The Golden Cherry claim, which was originally known as the Golden Chariot, was located about 1880. Later it was known as the Eureka and now as the Golden Cherry. Up to the present time about 970 feet of underground work has been done. The portal to the main tunnel is situated on the level of Peshastin creek about 2,000 feet south of Blewett and below the county road. The country rock is serpentine, but much fractured. Some ore was found in the south tunnel. The assessment work for the Tip Top group is now being done entirely in the Golden Cherry tunnel.

WILDER MINE.

This group consists of three claims known as the Ivanhoe, Kennilworth, and Amber Glee, situated on the north side of Culver gulch and over the divide down towards Negro creek. The Ivanhoe was originally known as the Hindoo, later as the White Elephant, and was first opened in 1881. It was re-located as the Ivanhoe in 1902 by James Wilder. The Kennilworth, which joins it on the north, and the Amber Glee, which is an extension on the east, were also located in the same year. The underground workings on the Ivanhoe consist of two tunnels driven in on the vein, one of which is 140 feet long and the other 160 feet, with a forty-foot cross-cut. This work was done in the years 1902 and 1906. The Kennilworth has one tunnel forty feet in length. The Amber Glee has one cross-cut tunnel driven north to the vein with a drift of 200 feet and an upraise of sixty feet.

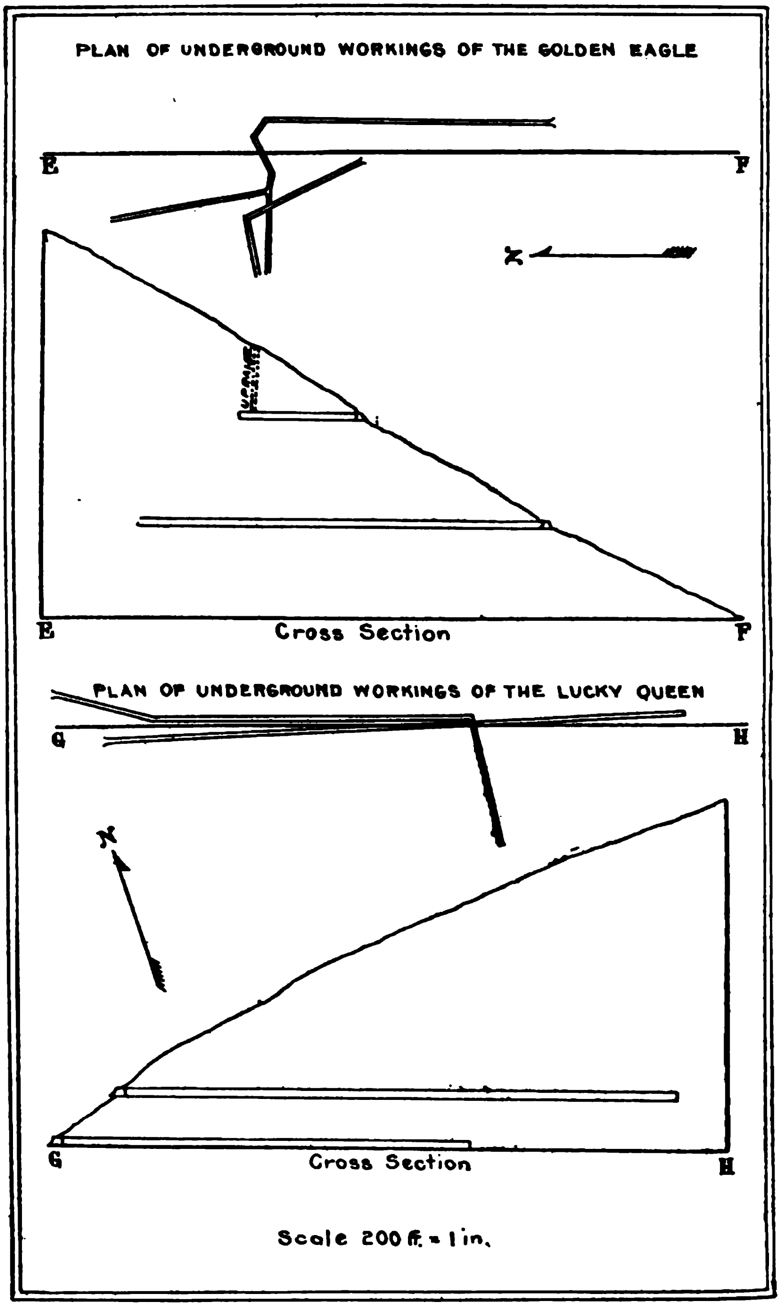
The width of the vein varies from two to six feet, carrying gold and a small amount of silver. The trend of the vein is nearly east and west, with a nearly vertical pitch. It is estimated that 150 tons of ore have been taken out, and assays made by Mr. Bogardus in 1906 yielded returns ranging from a trace to $72 per ton in gold with a very small amount of copper and silver.

GOLDEN GUINEA MINE.

This property consists of eight claims known as the Golden Guinea; Golden Guinea No. 1, east; Golden Guinea No. 1, south; Golden Guinea No. 2, south; the Brown claim; the Lillian; and the Copper Queen. They were first located in 1897 and were known as the Francis L. group. Later they were relocated in 1904 by R. F. Brown, of Leavenworth, and were named the Golden Guinea group. These claims are situated on the north and south slopes of Negro creek, about two miles above its mouth. Development work consists of 233 feet of tunnel on the Golden Guinea claim, with a shaft forty-three feet deep. On the Golden Guinea No. 1 south, a cross-cut tunnel has been driven south for a distance of fifty feet for the purpose of tapping the east-west vein. Several smaller tunnels and open cuts have been made on all of the claims. The Golden Guinea vein lies in the Hawkins formation and has a general trend of north 70° west. It is represented by a belt ranging from ten to fifty feet in width, composed of iron stained country rock, containing more or less discontinuous stringers of rusty, broken quartz, occupying a zone about two feet in width. When traced eastward this vein apparently is headed for the Golden Eagle vein in Culver gulch. No deep workings exist so that it is impossible at the present time to predict what future developments may show. Several assays were taken on these veins but none of them ran over $1 per ton in gold, although much higher returns are claimed to have been previously obtained. This property is owned by R. F. Brown and F. W. Losecamp, of Leavenworth, Washington.

LUCKY QUEEN MINE.

The Lucky Queen group consisting of the Lucky Queen and Bee Queen claims, is located a short distance north of Blewett on the east side of Peshastin creek, and adjoins the Blue Bell claim on the north. This claim was originally located by John


PLAN OF UNDERGROUND WORKINGS OF THE GOLDEN EAGLE
E
F
N
UPRAISE
E
Cross Section
F
PLAN OF UNDERGROUND WORKINGS OF THE LUCKY QUEEN
G
H
N
G
Cross Section
H
Scale 200 ft. = 1 in.

Plan of underground workings and cross-sections of Lucky Queen and Golden Eagle mines.

Ernest in 1889 but later passed into the hands of Peter Anderson and Thaddeus Neubaur in 1895. The development work on this property consists of two tunnels, one driven at the level of the county road and the other about forty feet higher. Altogether about 1,000 feet of tunnel have been driven. The lower tunnel extends in 425 feet from the mouth, and at the face, a cross-cut turns off at right angles for a distance of 120 feet. The vein is parallel to the main drift, composed of talc, calcite, and quartz, and varies in width from a mere stringer to three feet. In the upper tunnel a drift has been run in on the vein for a distance of 412 feet, which strikes north 78° west and pitches nearly vertical.

The ore in this vein is similar to that below and is known to have yielded rich specimens showing free gold.

BLUE BELL MINE.

The Blue Bell mine is situated one-quarter mile north of Blewett, on the east side of Peshastin creek, near the county road. This was located by John Bomaster in 1890, and was formerly known as the "I. X. L." The development work consists of about 450 feet of tunnel driven through a badly fractured and dislocated mass of serpentine. No well defined vein could be found. Many of the seams in the country rock are filled with vein material composed of quartz and calcite, with pyrite and some gold, but the strike and pitch varies from point to point. In some very small pockets, high values are reported to have been taken out by Mr. Bomaster, but none were seen by the writer at the time of examination. Eighty-five feet from the mouth of the tunnel the vein splits, the north wall is composed of iron stained serpentine, with many seams of calcite, and the south wall of ordinary green serpentine.

PROSPECT MINE.

This property is situated west of Blewett on the north slope of the ridge leading down to Culver Springs gulch, and extends from its head down nearly to Peshastin creek. It consists of a group of five claims known as the Sunset, the Sunset Extension, the Redjacket, the Lone Star, and the Katy, all of which are owned by the Prospect Mining & Milling Company. Openings have been made upon all of these claims and some of the ore was taken out in early days and treated in an arrastra. The development work on this property consists almost entirely of the required assessment work.

All of the workings on this property are situated in the serpentine formations and the vein material consists mainly of quartz, with calcite and talc, containing gold and a little silver. All of the openings are near the surface and consequently in the oxidized zone. The vein can be traced on the surface by the red iron-stained character of the serpentine and occasional outcrops of quartz.

HOMESTAKE MINE.

This claim lies on the west side of Peshastin creek, near the mouth of Culver Springs gulch. One hundred sixty-five feet of tunnel have been driven in on a quartz vein trending about north 75° west, and pitching nearly vertical. The wall rocks are iron stained serpentine, containing calcite seams. A general assay taken on this vein from the mouth of the face of the tunnel gave returns of 0.04 ounce in gold and 0.2 ounce in silver. It is possible that this vein represents the eastward extension of the Pole Pick. This property is owned by Mr. John Olden, of Blewett.

LONE ROCK PROSPECT.

This claim is situated on the east side of Peshastin creek just back of Blewett, on the slope of the hill leading up to Windmill point. No ore has ever been taken out and the development work has consisted entirely of assessment work. A tunnel eighty-eight feet in length has been driven on a narrow belt of red, iron-stained serpentine seamed with small stringers of calcite. A general assay of this rock was taken, which yielded returns of 0.02 ounces of gold and 0.2 ounces silver. This claim is owned by Mr. John Olden, of Blewett.

JOHNSON PROPERTY.

The Johnson property consists of three claims extending in a general east-west direction, about three-quarters of a mile north of Blewett, and extends from Peshastin creek easterly to the summit of the ridge leading down to Ruby creek. These three claims are known as the April Fool, the Venus, and the Donaldson.

The development work on this property consists of a tunnel about 100 feet long on the April Fool claim, driven on a vein pitching nearly vertical. On the Venus claim a tunnel has been driven in nearly 115 feet in a direction north 20° west. No vein was found here, however. On the Donaldson claim a tunnel was driven in for a distance of 195 feet directly east. This tunnel, however, was inaccessible at the time of examination, but is reported by Mr. Johnson to have encountered a diabase dike at a point sixty feet from the mouth. Beyond that point the Swauk conglomerate constitutes the south wall. A second tunnel has been driven on this same claim along the direction north 40° east for a distance of eighty feet. At the top of the ridge looking down into Ruby creek an open cut has been made on a four-foot vein composed of talc, with serpentine for both walls. About twenty-five feet to the south of this cut the basal beds of the Swauk formation outcrop. Assays made on this ore gave returns of 0.02 ounces gold and no silver. However, much higher assays are said to have been obtained from some of the ore extracted. These veins are not distinct but much broken and fractured. They cut through the Peshastin and peridotite formations and lie close to the contact with the Swauk sandstone.

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WASHINGTON GEOLOGICAL SURVEY

HENRY LANDES, State Geologist

BULLETIN No. 7

Geology and Ore Deposits of the Index Mining District

By CHARLES E. WEAVER

1889

OLYMPIA, WASH.:
E. L. BOARDMAN, PUBLIC PRINTER
1912

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LETTER OF TRANSMITTAL.

Governor M. E. Hay, Chairman, and Members of the Board of Geological Survey:

GENTLEMEN—I have the honor to submit herewith a report entitled "Geology and Ore Deposits of the Index Mining District," by Charles E. Weaver, with the recommendation that it be printed as Bulletin No. 7 of the Survey reports.

Very respectfully,
HENRY LANDES,
State Geologist.

University Station, Seattle, December 1, 1911.

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INTRODUCTION.

FIELD WORK AND ACKNOWELDGMENTS.

Geological field work in the Index Mining District was begun on August 2nd, 1910, and continued until September 20th of the same year. During this time the larger part of the areal geological mapping was completed, and many of the detailed underground examinations of the ore deposits were made. Later, during the autumn months of the same year, several shorter trips were undertaken for the purpose of completing the geological mapping and the examination of the individual mines.

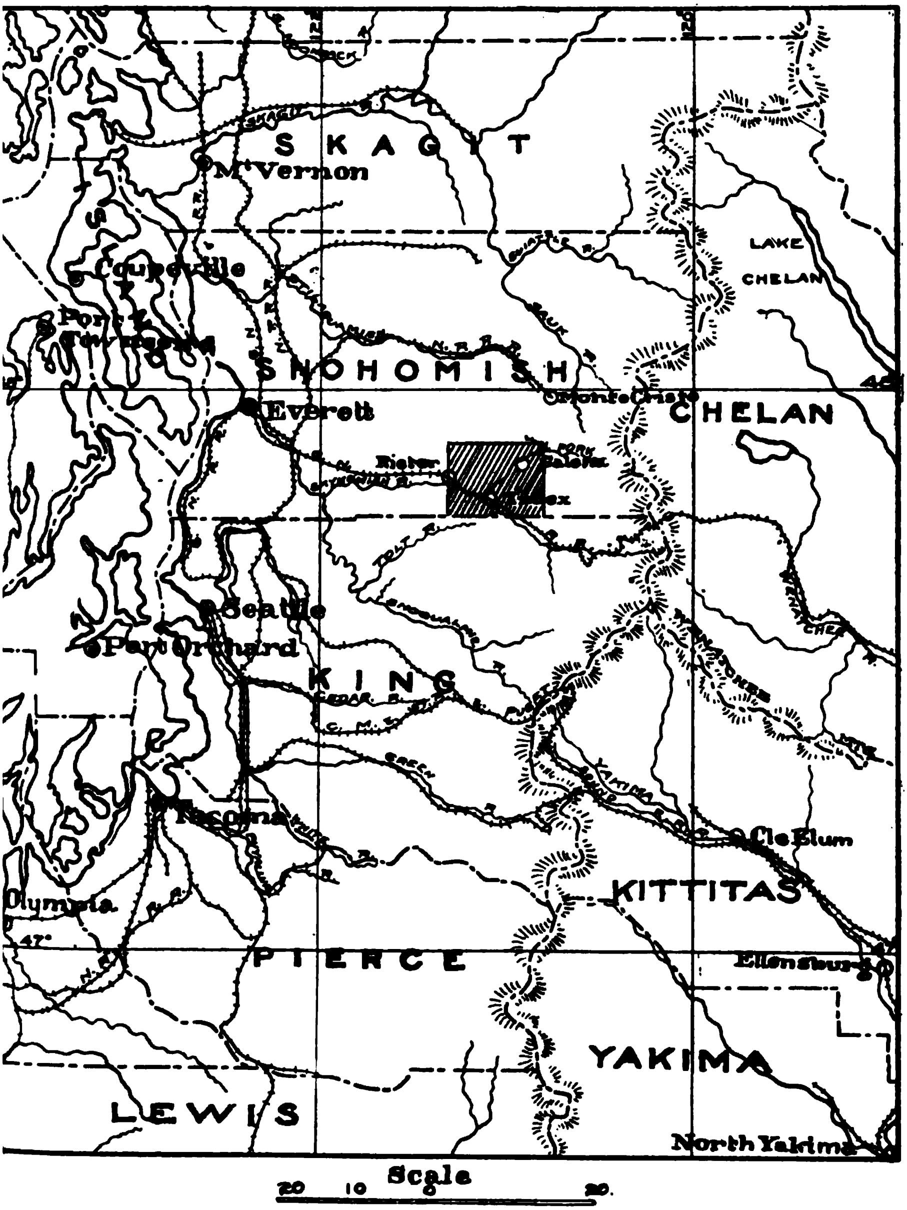
Mr. Charles R. Fettke assisted in surveying the trails as well as many of the tunnels and open cuts. He also assisted in the areal geological mapping and in some of the underground studies. The ore samples taken from the various mining properties were assayed by Professor C. R. Corey, of the College of Mines of the University of Washington.

The topographic map which is used as a base for representing the areal distribution of the geological formations occurring within this district was in part constructed from a photographic enlargement of a portion of the Skykomish quadrangle, published by the U. S. Geological Survey, and in part from the Snoqualmie topographic atlas made by the Forest Service of the United States Department of Agriculture. The former was enlarged from a scale of one-half inch to the mile, to a scale of one inch to the mile, and the Forest Service map, which already existed on the scale of nearly one inch to the mile, with 200-foot contours, was made to conform to it. The resulting map is on a scale of one inch to the mile with 100-foot contours. Wherever possible foot and compass surveys were made of the trails, and the cabins, mine openings and vein outcrops were tied in to some definitely located monument. Wherever mining maps, showing the plan of the underground workings, were not available, an attempt was made to construct them as accurately as possible by a tape and compass survey. On account of the extremely rough topography in parts of this district, it was impossible to actually traverse certain portions of the higher mountain crest lines and sharper pinnacles, but they were examined from every possible approach in order to determine their general character.

The writer wishes to express his thanks to the many mining men and prospectors, living or operating in this district, who have taken a deep interest in the progress of the investigation and who have given much personal assistance in carrying out this work in the field. Many of the smaller prospects and open cuts might have been overlooked if it had not been for their piloting the writer over the country. I wish to especially thank Mr. F. F. Otis, of the Non Pareil Mine, Mr. William Merchant, of the Merchant and Townsend property, and Mr. William Cornwall, of Index, for the facilities which they placed at the writer's disposal.

LOCATION AND AREA OF THE DISTRICT.

The Index Mining District is located in the southern part of Snohomish county, on the western side of the Cascade mountain divide, within the drainage area of the Puget Sound basin. Geographically it is situated in about latitude 47° and 50′ north, and longitude 121° and 30′ west, in the valley of the Skykomish, where the north and south forks of that river unite.



MAP OF PORTION OF CASCADE MOUNTAINS
SHOWING INDEX DISTRICT
WITH REFERENCE TO SURROUNDING COUNTRY.

▨ Area Representing Index Mining District.
Areal Geology Mapped.

The Index District is an unorganized mining district and as such has no well defined areal limits. Locally, however, all of the mining claims in the vicinity of the town of Index, as far east as the towns of Galena and Baring are referred to as belonging to the Index District. All of the claims on Silver creek north of Galena are a part of the Silver Creek Mining District, and those still farther north belong to the Monte Cristo and Silverton Mining districts. In this report the area chosen for investigation consists of about 100 square miles, and in the west central portion of it is situated the town of Index. The south boundary of this district is represented by the King-Snohomish county line; the western boundary is a line extending north and south through a point two and one-fourth miles directly west of the junction of the north and south forks of the Skykomish river; the eastern boundary extends north and south from the junction of Troublesome creek with the north fork of the Skykomish river; the north boundary extends east and west through a point about one mile north of the town of Galena on Silver creek.

INDUSTRIES AND SETTLEMENTS.

Mining and lumbering are the principal industries of this district, and upon them nearly all of the others depend. With the exception of a few scattered homesteads along the river flats, there is very little arable land. Immediately west of this district the Skykomish river valley broadens and is dotted with many dairy and hay ranches. There is some logged-off land, which, when cleared, can be used for agricultural purposes. The slopes of the larger valleys, as well as the majority of the smaller ones entering into these, are heavily clothed with good, merchantable timber, which is now being cut and hauled to the lumber mills situated along the line of the Great Northern railway. There is one large mill at Index and two more on the south fork of the Skykomish, between that town and Baring. Approximately 600 men are employed in this industry.

The mines and prospects are distributed over the entire district and are connected with the towns on the railroad lines by road, tram, or trail. Index is the largest settlement, with a population of 450, and is situated near the junction of the north and south forks of the Skykomish river. It is located on the main line of the Great Northern railway and is the chief distributing point for supplies in the district. Baring is the second town of importance, with a population of 200, situated on the Great Northern railway, nine miles east of Index, and is located on the south boundary of the map. Halford, also located on the Great Northern railway, is the third town of importance and owes its existence largely to the granite quarry immediately west of the town. Reiter is merely a stopping point on the Great Northern about five miles west of Index, with side track and water tank, and is connected with the Bunker Hill mine, about one mile to the north, by a surface tram road. Galena, an old settlement at the junction of Silver creek and the north fork of the Skykomish, was formerly a local base of supplies for the miners in that vicinity, but is now practically deserted. It is connected with Index by a good wagon road, nine miles in length and built along the north fork of the Skykomish river. From Galena a wagon road has also been built northward up Silver creek as far as the mining town of Mineral City.

In addition to these small settlements, many cabins may be found on the different creeks which are occupied by miners and homesteaders.

LITERATURE.

Very little has ever been written concerning the geology of the western portion of the Cascade mountains in the State of Washington. Only one geological folio has as yet been published, and that describes an area mainly within the drift-covered portion of the Puget Sound basin. No areal geological work has ever been done in the Index district and scattered references to the mines are very meagre. In the following list of publications, not only those papers directly referring to the Index district are given, but also those which describe and discuss the geology in other parts of the western Cascade mountains, and which seem to be closely related to the geology of this district. A short abstract with occasional quotations are given of those reports most closely related to the problems here involved:

Hodges, L. K. Mining in the Pacific Northwest, Index District, pp. 33-35, Silver Creek District, pp. 26-33. Published by the Post-Intelligencer, Seattle, Washington, 1897.

In this report a short description is given of each of the mining properties which had been located prior to the year 1897. The character of the ore, and its relation to the country rock is described. The geology of the district is characterized as "metamorphic granite diked with fine grained trap and a conglomerate overlaid with magnesium limestone. Cutting up into this are masses of diorite which in turn are later cut by a series of mineralized ledges having a north-west to southeast and a north to south direction." The Silver Creek district, which lies immediately to the northeast, is considered to be similar in character and to represent the southern extension of the Monte Cristo district.

Russell, Israel C. The Cascade Mountains in Northern Washington, 20th Annual Report, U. S. Geological Survey, Part II, pp. 82-210, 1898, Washington, D. C.

This paper presents the results of a geological reconnoissance made on both the east and west sides of the Cascade mountains. The area involved in the Index district was not visited, but an examination was made of the formations extending from the Cascade divide westward past Monte Cristo down the Sauk valley to Darrington, and also from this divide down the Skagit valley to Marblemount. Mr. Russell describes these formations as slates, schists, greenstones, granites, and overlying volcanic rocks, ranging in age from Paleozoic to late Tertiary, which had been much folded and contorted and then uplifted above sea level about 8,000 feet as an "elongated, nearly flat-topped dome, all the central part having the characteristic features of a plateau." He regards this as having been dissected by streams flowing both to the east and to the west and that the conditions on the west side were much more favorable for stream work than those on the east side, resulting in wider and much more dissected valleys. The general conditions involved in the glaciation of the west slope of the Cascades is discussed. Mr. Russell states, p. 172: "During the Glacial Epoch the Cascade mountains in northern Washington were heavily snow covered and gave origin to large glaciers of the alpine type. These flowed both east and west from the main divide, down previously deeply eroded stream valleys. The snow fields from which large trunk glaciers descended on the higher portions of the eastern slope of the mountains were confluent. On the west side of the main divide the snow fields were broader and thicker than on the east side—so thick, in fact, that when the glacial conditions were at their maximum a general ice sheet was formed which buried some of the most prominent ridges, especially in the northern portion of the region under consideration. It seems possible that along the northern portion of the Cascade divide in northern Washington, the snow was piled so high on the west side of the main divide that the snow divide was some distance west of the present rock divide." And on page 173, he states: "The westward-flowing glaciers drained a vast series of confluent snow fields, which, during times of maximum glaciation, formed a continuous ice sheet on all the higher portions of the western slope of the mountains. The trunk glaciers flowing from this ice sheet were, in general, broader and thicker than the similar glaciers on the east side of the range, and became true alpine glaciers of the character of the Seward glacier, Alaska, but expanded and united at their lower extremities and assisted in forming a large piedmont glacier which occupied Puget Sound basin. This piedmont glacier had two stages of broad expansion, separated by an interglacial stage, during which thick gravel deposits, together with layers of peat, were spread out on top of a basement layer of till." In this report no mention is made of the ore deposits in the Index district.

THYNG, WM. S. The Index District, pp. 114-120, 1st Ann. Rpt., Washington Geological Survey, Landes, Olympia, Wash., 1901.

In this report the more important mines are described, including the character of the ore and the amount of development work undertaken. Concerning the geology, he states the following: "The fundamental formation of the district is granite, which is in places crossed by dikes of trap, and at other points is overlaid with what appears to be slate, probably metamorphosed shale, and which is considerably altered and softened at the surface. Small amounts of impure limestone are also found at certain points. So far as development has progressed, there appears to be but little uniformity in the trend or direction of the important ore bodies, but by far the greater part of the ledges appear to be fissure veins cutting the granite formation. The typical ores are chalcopyrite and bornite, the latter being generally found in greater proportions as depth is obtained." * * * "Gold is not usual * * * some veins have been discovered of what may be fairly considered as true gold ore, this gold ore is claimed to be free milling, although the properties have never been worked. Index is therefore to be properly considered, a copper mining district."

THYNG, WM. S. Silver Creek District, pp. 111-114, 1st Ann. Rpt. Wash. Geological Survey, Landes, Olympia, Wash., 1901.

This district is considered as the connecting link between the Monte Cristo district on the north and the Index district on the south. The country rock is described as being mainly granite and the ore in the upper part of the district principally copper and iron, carrying values in gold and silver. In the lower portion, just above the town of Galena, some silver-lead ore with subordinate amounts of copper pyrite carrying some gold are found.

The mines in this district are tributary to Index by means of a wagon road up the north fork of the Skykomish river, from Index to Galena and from there by another road up Silver creek. The geology of this district is described as follows, page 112: "The country rock of the district is mainly granite, less of the overlying sedimentary rocks being found than at Silverton to the north. The granite outcrops at a number of points along the entire length of Silver creek. The ore bodies are mostly true fissure veins which have a general trend a little to the south of east. The ledges or veins are cut and faulted to some extent by probably a later series of fissure which appear to have a general direction or strike of northeast and southwest.” A description of the underground workings and the character of the ore bodies is given for each of the important mining properties.

Spurr, Joseph E. Ore Deposits of Monte Cristo, Washington, 22nd Ann. Rpt., U. S. Geological Survey, 1900-01. Part II., pp., 777-888, Washington, D. C., 1901.

This paper presents the results of some detailed geological investigations made in the Monte Cristo Mining District in the State of Washington. The district is situated in Snohomish county, on the western slope of the Cascade mountains about 40 miles east from Everett and about 10 miles northeast of the town of Index. The results obtained here are of importance when considered in connection with the geology of the Index district, because of its proximity to Index and because it is the only detailed geological report on the western slope of the Cascades. An area of about 20 square miles was chosen and geologically mapped. The topography of this area is exceedingly rugged and with several fields of perpetual snow in the form of alpine glaciers occupying depressions on the high mountain crests.

The following geological divisions have been made in this district, p. 788:

1.	Ancient granitic rock, not exposed	Mesozoic
2.	Arkoses and conglomerates with some quartzites	Eocene
3.	Earlier andesites and tuffs	Miocene
4.	Tonalite (dacite)	
5.	Rhyolite	
6.	Basaltic rocks	

7. Pyroxene-hornblende-andesites, tuffs and volcanic breccias ....Late Pliocene-Pleistocene

Insomuch as the topographic and geological features and the processes of ore deposition of the Index and Monte Cristo districts are closely associated, it seems desirable to state Mr. Spurr's ideas concerning the latter district. The following statement is quoted from his summary on pp. 863-864:

"The rock series of the Monte Cristo district has at its base a hypothetical granite, not actually determined, although recognized in other neighboring districts. The lowest actually determined formation seems to be a series of heavy arkoses. These are capped by thick andesitic tuffs and flows, and these by thick basalts, with a sparing amount of rhyolite, which is probably intermediate in age between the andesites and the basalts in general. The basalts are overlain by later andesites which constitute the youngest of the rocks. Probably between periods of the early andesites and the basalts came intrusions of tonalite, which by contact metamorphism transformed narrow zones of the intruded rock into silicified phases and schists.

"These rock formations are all Tertiary, ranging from Eocene to late Pliocene or early Pleistocene. In late Tertiary times the rocks (with the exception of the later andesite, which was not yet poured out) were folded and subsequently planed down by erosion. Then in late Pliocene or early Pleistocene time came an uplift of the planed surface to form a plateau. This uplift was accompanied by the extrusion of the later andesite and by fracturing. Immediately after the inception of the uplift, the dissection of the present topography began, and with it the deposition of the ores.

"These ores have formed chiefly along the joints and fractures, and are often especially localized at the intersection of different fractures. The areas of most profound fracturing are in general the areas of greatest mineralization. The ores are especially abundant in the tonalite; to a less extent in the andesite.

"In the observed veins of the district it is found that the ores are most abundant near the surface. There is a rough succession from the surface downward, of galena, blende, chalcopyrite, pyrite, and arsenopyrite. The upper zones characterized by galena, blende, and chalcopyrite, contain more gold and silver than the lower zones, characterized by pyrite and arsenopyrite.

"Upon various grounds it has been concluded that the upper sulphide zone, which contains the most and the richest ore, was deposited, largely at least, since the development of approximately the present topography, by downward-trending waters. Lead, one of the most conspicuous metals of this zone, is not known to be present in the lowest ores, and so is not regarded as having been derived by the concentration of ores like those in the lowest zones; but is, perhaps, as the known facts indicate, an original deposit by descending waters. This theory involves the derivation of the lead ores, from the surrounding rock. The lower sulphide zones afford less evidence as to their origin, but what there is tends into the same direction as that for the upper zones, so that the general suggestion is deduced that all the zones were precipitated, in part simultaneously, by downward percolating waters, the different belts of minerals being precipitated in order according to their relative solubility. Similar phenomena in other regions, and the known chemistry of such phenomena, support these deductions from independent local evidence."

GEOLOGY AND ORE DEPOSITS OF THE INDEX MINING DISTRICT.

CHAPTER I.

PHYSIOGRAPHY.

TOPOGRAPHY.

General Statement.—The topography of the Index Mining District, in common with that of the western slope of the Cascade mountains, is extremely bold and rugged. The central portion of the range extending from the Snoqualmie river on the west to the Columbia on the east—a distance of about seventy-five miles, comprising Chelan, Snohomish and King counties, presents a broad elevated mountain mass deeply dissected by several large valleys. These extend eastward to the Columbia river and westward to Puget Sound and head at intervals along a north-south line which represents the Cascade divide and lies a little to the west of the center of the range. At the present time this elevated mountain mass has a maximum elevation ranging from 6,000 to 8,000 feet along the main divide, with a gradual decrease eastward to the Columbia river, where the elevation is 1,000 feet, and a more rapid decrease to the westward to sea level. Observations made from some of the higher peaks on the western slope of the mountains show the summits of the crest lines between the larger stream valleys to accord in level with a gradual slope to the west.

The large trunk streams heading near the divide and flowing westward are the Snoqualmie, Skykomish, Stillaguamish and Skagit. Those flowing to the east are the Wenatchee and Yakima. The Index district lies about fifteen miles west of the main divide and entirely within the drainage basin of the Skykomish river. This river, including the north and south forks, together with numerous smaller tributary streams, has deeply dissected the area, leaving deep valleys with steep slopes, and high ridges with saw-tooth crests which are often inaccessible. High up in these divides, especially near the sources of the larger creeks, are glacial cirques, generally containing small, rock-rimmed lakes, surrounded with talus slopes. One of the most prominent topographic features of the Index district is a high, mountainous mass, lying between the north and south forks of the Skykomish river and culminating in Gunn peak and Mount Index. To the south of the town of Index, on the south side of the Skykomish river, are west Mt. Index and Mt. Persis, which project as pinnacles from the crest of the ridge between the Skykomish and Tolt river valleys.

DRAINAGE.—The drainage of the western slope of the Cascade mountains in the State of Washington is accomplished through several large river valleys, with their numerous branches, which head near the crest of the range and find their outlet through Puget Sound and the lower portion of the Columbia river. The largest of these streams, beginning at the north in Whatcom county, are the Nooksack, Skagit, Stillaguamish, Skykomish, Snoqualmie, Cedar, Green, White and Nisqually rivers, all of which drain to Puget Sound. Farther south are the Cowlitz and Lewis rivers, which find their way to the Columbia.

All of these river valleys are characterized by narrow canyons with extremely high grades and numerous waterfalls in their upper courses, by broader valleys with medium grades along their middle stretches, and by broad alluvial plains near the Sound.

The drainage within the Index district proper is almost entirely through the north and south forks of the Skykomish river. An extremely small area in the southwestern portion of the district is within the drainage basin of the Tolt river. The north and south forks of the Skykomish river join about one mile west of Index, forming the Skykomish river proper. Draining into this from the north and west of Index are Deer, Hogarty, May and Wallace creeks. The area to the south of the Skykomish is drained chiefly by Proctor creek, which finds its way into the Skykomish river about three miles to the west of the limits of the map. The area to the north of the north fork of the Skykomish river is drained by Silver creek, which empties into the north fork of the Skykomish at the town of Galena and by Salmon, Excelsior, Curry and North Star creeks. The area between the north and south forks of the Skykomish is drained by a number of creeks flowing northward and others flowing southward, separated by a group of high, rugged mountain peaks—represented within this district by the Gunn peak and Mt. Index mountain mass. The most important of those creeks flowing northward are Howard, Bitter, Canyon and Lewis creeks. Of those flowing southward, Barclay creek is the most prominent. The area on the south of the Skykomish is drained by three northward flowing creeks, namely: Anderson creek, Bridal Veil creek and Philadelphia creek.

The elevation on the north fork of the Skykomish river in the northeast corner of the district is 1,300 feet. This gradually decreases for a distance of 12 miles, where at the town of Index, it is 528 feet. On the south fork of the Skykomish, near the southern boundary of the map, at the town of Baring, the elevation is 759 feet, which in a distance of eight miles, at the junction of the north and south forks of the Skykomish, drops 230 feet.

An area of about twelve square miles in the eastern part of the district is drained by Trout creek, which empties into the north fork of the Skykomish river, about midway between Index and Galena. This creek is about eight miles in length and carries a considerable volume of water throughout the year. On the north and east side of this valley, is a high, rugged ridge forming Iron mountain. About five miles from the junction of the north fork of the Skykomish with Trout creek, the latter divides into a north and south branch, each of which is partially fed by a small, rock-rimmed lake, situated in an amphitheater of glacial origin at its head. The water from these lakes is drained through narrow outlets and tumbles down the slopes of the valleys in a series of cascades.

On the east side of Iron mountain is located Howard creek, draining an area of about nine square miles and occupying a deep canyon between Iron and Spire mountains. This stream rises in Howard lake at an elevation of about 4,000 feet, and flows northeasterly for a distance of five miles, where it joins the north fork of the Skykomish about one miles below Galena, at an elevation of 1,050 feet.

Bitter creek, lying to the south of Trout creek, and approximately parallel to it, drains an area of four square miles, and empties into the north fork. Barclay creek, still farther south, rises in a small glacial lake, on the north side of Mt. Index, drains an area of about eight square miles and empties into the south fork of the Skykomish about one mile west of the town of Baring. This creek is about seven miles long and decreases gradually from an elevation of 3,500 feet at its head to 800 feet at its mouth.

All of these streams contain more or less water throughout the entire year, and many of them during the winter freshets become raging torrents, and as such are a very active factor in erosion. On account of the great volume and the precipitous courses of these streams, much power is available for economic uses.

FORMS OF THE SURFACE.—The maximum elevation attained within this district is on Gunn peak, 6,245 feet. This is situated in the southwestern portion of the area, and constitutes the highest part of an extremely rugged, mountainous mass, forming the water shed between the north and south forks of the Skykomish river. To the south of Gunn peak, on the southern border of the district, is Mt. Index, with an elevation of 6,125 feet and separated from the Gunn peak mass by the deep valley carved out by Barclay creek. To the east of Gunn peak mass, lies a steep, bold series of mountain ridges, ranging in elevation from 5,200 to 6,000 feet and separated from it by the deep, erosional valley of Trout creek. The higher peaks in this elevated region consist of Merchant peak, 5,465 feet; Conglomerate point, 5,320 feet; Iron mountain, 5,241 feet; and Spire mountain, 6,065 feet. Still farther east, beyond the limits of this district, this mountainous area gradually increases in elevation to an average of 7,000 feet, near the Cascade divide. In a westerly direction it decreases to an elevation of about 800 feet along the north fork of the Skykomish river. Northwest from the north fork of the Skykomish river, the elevation rapidly increases about 3,000 feet in two miles, resulting in a long, northeast to southwest ridge whose crest line is a part of an elevated plane which increases in elevation to the north about 100 feet to the mile. Parallel to the long ridge just mentioned are two others in the northwest portion of the district, whose elevated crest lines can be accounted for as remnants of this elevated, northward sloping plane. The parallelism of these ridges may be accounted for by the general northeast southwest trend of Hogarty and Wallace creeks, which have carved out deep canyons into this plane, leaving between them sharp divides.

In the southwestern portion of the district is a steep mountain mass rising from the south fork of the Skykomish river at an elevation of 500 feet to 4,000 feet in a distance of one and three-fourths miles. This mass forms the divide between the drainage basin of the Skykomish river on the north and that of the Tolt river on the south. That portion of the crest line occurring in this district is situated on the extreme southwestern border extending nearly east and west and reaching a maximum elevation of 4,600 feet in the high spire of Mt. West Index. This mountainous area is cut up into steep, elongated spurs by several northward flowing creeks which find their way to the Skykomish river.

GLACIATION.

Glaciers have played a very important part in the physiography of the Cascade mountains. On both the eastern and western slopes pronounced evidences of extensive glaciation may be seen in all of the river valleys from the crest of the divide to Columbia river and Puget Sound. Glaciers developed in both the northern and southern portions of the range, but were much more extensive in the former.

Many small alpine glaciers are still in existence on the flanks of the higher peaks and ridges and on the slopes of some of the lofty volcanic cones. But the most important ones developed during Pleistocene time and were contemporaneous with at least a part of the great Continental glaciers which covered so large a part of the northern portion of the North American continent.

The facts as observed to the west of the Cascades in the Puget Sound region indicate two distinct periods of glaciation separated by an interglacial period during which the earlier ice streams had retreated far up into the main trunk valleys leading down from the crest of the Cascades. The evidence is the superposition of two different glacial deposits along the western foothills of the range. The ideas held concerning the glaciation of the Puget Sound basin are that as the glacial period gradually advanced, glaciers began to develop in the higher altitudes near the summit of the range and as they increased in size, flowed both to the east and west through the erosional valleys as long streams of ice. Ultimately those on the west reached Puget Sound and coalesced, and together with the great tongues of ice coming southward through the straits of Rosario from British Columbia, united to form a broad belt of ice occupying nearly all of the Puget Sound basin from the Cascades to the Olympic mountains. These westward flowing streams of ice seem to have gradually increased in volume and to have filled all of the smaller valleys and in many cases to have covered over the divides between them. The evidence for this may be found in the occurrence of glacial drift not only on the slopes of the valleys but also on the crests of the mountains separating them.

Finally as the climate became warmer and the ice streams began to retreat, thick deposits of rock debris were left behind in the trail of the glacial stream as moraines. As the ice finally disappeared the heads of the larger valleys and some of the smaller ones leading to them were marked by many small, rock-rimmed lakes situated in cirques or glacial amphitheaters which originally were the gathering grounds for the large ice streams. Prior to the advent of the glaciers, valleys due largely to stream erosion and characterized by steep V-shaped canyons drained the country from the Cascade divide westward. During glaciation the large ice streams modified the pre-glacial valleys by scouring and rounding their slopes and developing the characteristic U-shaped valleys. The present condition of the topography is largely due to this process.

The area involved in the Index district, which is situated well up in the Cascade mountains, has been extensively glaciated in common with the western slope of the range. Two large glaciers flowed down the north and south forks of the Skykomish river and joined in the vicinity of the town of Index. From there they traveled westward as one ice stream through the Skykomish valley to Puget Sound. At intervals along their course, the two ice streams just mentioned received lateral feeders, several of which had their gathering ground within the area of this district. Two rock-rimmed basins or cirques now occupied by lakes, occur at the heads of the north and south forks of Trout creek. Each of these, in common with a majority of the others to be mentioned, are surrouned by steep talus slopes. The slopes of the valley of Trout creek, to an elevation of 1,000 feet above the creek bed, are covered with glacial drift. At the head of Howard and Barclay creeks glacial cirques occur and the valleys leading from them show the same pronounced effect of glaciation. Salmon, Wallace and Hogarty creeks also represent pre-glacial stream valleys which have been rounded and scoured by small ice streams leading down to the main Skykomish valley glaciers. Along the slopes of the Skykomish valley evidences of glacial drift may be seen up to an elevation of 1,000 feet above the river bottom. To the west of the town of Index, the glacial material assumes a considerable thickness and through this the Skykomish river has re-excavated its channel to its present position.

CLIMATE.

The climate of the Index district presents a wide range of variation. The annual rainfall in common with that of the western slope of the Cascades, is heavy. In the more highly elevated portions of the district, the precipitation is much higher than at the town of Index and during the winter months a considerable portion of it is in the form of snow. The following table compiled from the United States weather reports* gives the monthly and annual precipitation for Index and Monte Cristo:

MONTE CRISTO.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1895	......	......	9.39	9.60	11.74	2.24	2.20	0.71	11.45	1.70	10.92	28.14	......
1896	16.43	15.36	8.71	6.48	5.80	5.12	T	1.29	2.75	5.85	17.50	......	......
1899	......	15.07	8.40	10.87	8.08	5.88	......	......	3.40	10.21	25.26	15 07	......
1900	13.80	15.23	13.24	4.96	13.62	10.92	2.84	......	......	......	......	......	......
1901	......	16.09	10.40	9.45	4.71	8.33	1.97	0.17	6.27	8.48	......	......	......
Mns.	15.12	15.44	10.08	8.26	8.78	6.40	1.75	0.72	5.97	6.55	17.89	21.60	118.56

The data given for Monte Cristo is representative of the high mountainous region about Trout, Howard and Barclay creeks, while that given for Index applies to the town and valley of the Skykomish.

INDEX.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1894	......	......	......	......	......	......	......	......	......	10.33	16.61	8.84	......
1895	13.91	8.35	8.40	......	......	......	......	......	......	......	......	......	......
1904	......	......	......	......	2.45	5.25	2.55	0.54	1.69	5.10	25.65	15.37	......
1905	10.94	9.28	11.64	3.79	6.80	4.44	1.10	4.02	6.02	......	......	......	......
Mns.	12.42	8.82	10.02	3.79	4.62	4.84	1.82	2.28	3.86	7.72	21.13	12.10	93.42

The temperature varies in different parts of the district. In the eastern portion it is somewhat cooler than at the town of

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*U. S. Department of Agriculture, Weather Bureau, Summary of the Climatological Data for Western Washington, Section 19, by G. N. Salisbury.

Index and even there it is only slightly colder than at Everett or Seattle. No records are available for the town of Index. For Monte Cristo the mean temperature throughout the year is as follows:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
33.6	31.9	36.6	40.9	45.9	52.8	61.0	63.0	53.8	50.8	38.4	35.6	45.4

In the high mountain areas snow begins falling in October and does not disappear until late in May and in the more favored and elevated spots where the sun does not have free access, it often remains throughout the entire year. On the highest mountain ridges snow flurries may occur even during July and August. In the valley of the Skykomish where the elevation ranges from 350 to 500 feet, only occasionally does snow fall and then it rapidly disappears.

VEGETATION.

A large part of this district, up to an elevation of 3,000 feet, is heavily covered with a thick growth of timber consisting largely of red fir, white fir, and red cedar. In the zone ranging from 3,000 to 5,000 feet the timber is neither so large nor thick, the trees most common being white pine, noble and lovely fir, Engelmann spruce, tamarack, Alaska cedar, Merten's hemlock, and yew. Above the 5,000 feet elevation zone the trees are small, often scrubby, and of a sub-alpine character, chiefly the sub-alpine fir and Patton's hemlock. Because of the great amount of moisture, the valley bottoms and mountain slopes support a luxuriant growth of ferns, mosses and devil's club. Those areas which have been burned over or logged-off support a thick undergrowth of salmon berry, blackberry, raspberry and huckleberry bushes, together with vine maple, rendering travel almost impossible. Much of the timber along the north and south forks of the Skykomish is now being cut and prepared for the market at the mills situated along the line of the Great Northern Railway.

RELATION OF THE PRESENT TOPOGRAPHY TO THE GENERAL GEOLOGY.

The present topography of the Index district has been produced by the same causes which have developed that of the western portion of the central Cascades. Insomuch as very little investigative work has been undertaken in the western part of the Cascade mountains, our knowledge of its physiography is very limited. The ideas set forth in this discussion are the interpretation of the facts gathered within the district considered, in connection with previous studies made to the north in the Stillaguamish valley and to the south in the Snoqualmie valley, together with published information concerning the physiography and structural movements on the eastern side of the Cascade mountains.

The factors which have been most important in developing the topography on the west slope of the mountains are a series of uplifts accompanied by folding, peneplaination, and warping of the mountain mass, the consequent adjustment of streams to structure, and the final modification of the stream valleys by glaciation and subsequent erosion. Observations taken from several of the higher peaks within the Index district between the valleys of the Sauk to the north and that of the Skykomish to the south show many ridges and peaks conforming in altitude and lying in a plane whose general slope gradually decreases to the south towards the valley of the Skykomish. To the north there is a much steeper descent to the valley of the Sauk and Skagit. The suggestion at once arises that this region represents an uplifted peneplain, characterized by a long southeast to northwest axial warp, which has been deeply dissected by stream erosion. The axis of this warped structure is seen in a prominent divide, beginning at the summit of the Cascades near Cady pass at an elevation of about 4,400 feet and extending northwesterly through Columbia peak and the high mountains north of Monte Cristo out toward the Sound, where it seems to continue as a prominent topographic feature into the San Juan island group and on beyond to Vancouver Island.

The western portion of this spur of the Cascades is extremely complex and has been subjected to other deformational movements which were perhaps even more influential in shaping the topography than those which formed the spur further to the east. For the sake of reference, this spur will be called the Skykomish mountain uplift. One of the characteristic features of this uplift is the length and distribution of the lateral drainage lines. Those on the north side are short, with steep grades, and flow straight down to the Sauk, while those on the south are three or four times as long, with much lower grades and broader valleys. It is also worthy of mention that the high mountain ridge to the south of the Skykomish river, which forms the divide between that river and the Snoqualmie, is similar in character, having short streams with high grades draining northward directly to the Skykomish river, and longer streams with lower grades draining southward to the Snoqualmie river.

Investigations made by Russell,* Willis† and Smith‡ on the eastern slope of the Cascade mountains have accounted for the origin of that long spur of the Cascades which forms the divide between the Yakima and Wenatchee valleys, known as the Wenatchee mountains. This extends from the Columbia river northwesterly through Mt. Stewart to the Cascade divide. They attribute it to a deformational uplift of that portion of the mountains resulting in a long southeast northwest axial warp. The continuation of this Wenatchee uplift northwesterly across the summit becomes a part of the Skykomish mountain uplift.

The explanation given to account for the topography on the western side of the Cascades in the region near Index, is only tentative and future detailed investigations in the central and northern portions of the western Cascades will probably revise, if not altogether change these ideas. Proceeding on the hypothesis just outlined, the topography of this district is a part of the southern slope of the Skykomish mountain uplift. The north fork of the Skykomish river, Silver creek, Hogarty and Wallace creeks, are all southward flowing streams draining the more elevated areas to the north. Sufficient facts have not been obtained to warrant a discussion of the early Tertiary structural movements which have affected this region. From evidence already stated, it is assumed that during late Tertiary times the region was reduced to a peneplain and then perhaps during late Pliocene or early Quaternary, uplifted to an elevation of more than 7,000 feet above sea level and subjected to differential deformation, resulting in a long axial warp extending in a northwesterly direction between the present position of the Skykomish and the Sauk rivers, from the Cascade summit to the Puget Sound basin. This uplift is considered to have been contemporaneous with and to have been produced by the same causes which produced the Wenatchee uplift on the eastern side of the Cascades. It is possible, although not certain, that northwest southeast faulting accompanied this uplift, resulting in a series of tilted fault blocks, accounting for the rather steep escarpment on the north side of the ridge toward the valley of the Sauk, and the more gentle slope towards the valley of the Skykomish and the repetition of this is in the divide between the Skykomish and Snoqualmie.

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*Cascade Mts. in Northern Washington. 20 Annual Rpt. U. S. Geol. Survey, Part 2, pp. 140-145. 1899.

†Contributions to the Geology of Washington. Professional paper No. 19, page 91. 1903.

‡Mount Stuart Geological Folio, pp. 2 and 3.

During the progress of the uplift of the Skykomish mountain mass, drainage lines began to develop both to the north and south, giving rise to the present valleys of the Sauk and the Skykomish. Lateral streams soon developed and carved out canyons, the longer ones extending to the Skykomish and the shorter ones leading down directly to the Sauk river. Farther to the west other structural movements were also involved, making the process of topographic development more complex and difficult of explanation with the information which we have at present.

The topography produced as the result of deformation and consequent stream erosion was still further modified by glacial erosion and deposition. Great streams of ice moved down the stream erosional valleys, scouring their bottoms and rounding their slopes, and removing a tremendous amount of rock debris, which was carried down toward the Sound and finally dropped as the glaciers began to retreat, forming a thick deposit of glacial drift. As these ice streams finally moved back up the valleys from which they came, they left them partly filled with unassorted gravel, sand and clay and overlain with stratified gravels and sand deposited by streams issuing from the margins of the glaciers. Post-Glacial stream erosion has re-excavated these channels, which may be well seen near the junction of the north and south forks of the Skykomish river, west of the town of Index.

As the result of glaciation the headwaters of many of the streams high up in the mountains are characterized by glacial amphitheaters, many of which contain small glacial lakes with small outlets, having the relation of hanging valleys to the larger creeks into which they empty. The slopes of these larger creeks are covered with glacial drift for more than a thousand feet above the creek beds.

CHAPTER II.

GENERAL GEOLOGY.

GENERAL STATEMENT.

The geological formations involved in the Index district comprise igneous, metamorphic, and sedimentary rocks, including glacial drift. These occur in the Cascade mountains both to the north, south and east of this district. They have never been described, with the exception of the granodiorite, which, in a general way, has been referred to by I. C. Russell as granite.*

The determination of the geological age of the formations occurring in the Index district will, of necessity, be largely based upon our knowledge of similar formations occurring to the north in the Monte Cristo district, and to the east in the Snoqualmie and Mount Stuart regions where more detailed studies have been made. The oldest rocks are a thick series of metamorphosed sediments composed of quartzites, slates, crystalline limestone, cherts and schists, together with interbedded igneous flows. These rocks have been extensively metamorphosed and the subsequent movements to which they have been subjected have rendered it almost impossible to work out any definite structure or to subdivide the series upon a stratigraphical basis. This formation will be designated in this report as the Gunn peak formation, because of its typical development in that region, and its age seems to be most certainly Pre-Cretaceous. The next younger formation is a part of a great batholith of granodiorite which underlies a large part of the Cascade mountains and which also is represented in British Columbia and further to the south in Oregon and California. It resembles very closely the Mount Stuart granodiorite on the eastern side of the Cascade mountains, but in this report will be designated as the Index granodiorite. Following the intrusion of this plutonic mass into the earth's crust, there was a long period of erosion, during which time a large part of the overlying sediments were removed by stream action. During early Eocene this region was subjected to mountain making movements which resulted in the formation of extensive lake basins and the sediments accumulating in them within this district are represented by a series of granitic arkose and intercalated lava flows. After the deposition of the arkose series, this region was intruded by a series of basic dikes, and following the intrusion of these came outflows of andesitic lavas and tuffs. At some time late in the Pliocene or perhaps in early Pleistocene, the Cascade mountains were uplifted and stream erosion began its work of carving out the valleys, among which within this district are the north and south forks of the Skykomish. Later, during Pleistocene time, great valley glaciers began their advance down towards Puget Sound, removing as they went great volumes of rock from the mountain areas. This material now forms a thick veneer over the older rock formation and constitutes the glacial drift.

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*Twentieth Annual Report, Pt. II., p. 107, U. S. Geological Survey, Washington, D. C., 1899.

GUNN PEAK FORMATION.

Areal Distribution.—This formation is widely distributed in the southeastern part of the district, where it covers an area of approximately sixteen square miles. Beginning in the northeast corner it forms a belt about one and one-half miles in width, one-half lying on either side of Silver creek above the junction of that creek with the north fork of the Skykomish, at the town of Galena. This belt extends in a southerly direction and the western boundary lies about one-half mile west of Lost creek. From here it passes along the western side of Iron mountain and extends along the eastern side of Trout creek valley to a point about five miles above the mouth of Trout creek, where it crosses that creek and swings southwesterly, passing along the southern slope of Headquarter peak and diagonally cutting across the high rugged ridge forming the divide between Bitter creek and Lewis creek. It crosses Lewis creek at an elevation of about 3,000 feet and then swings to the south around the divide between Lewis and Barclay creeks and gradually decreases from an elevation of 2,900 feet to about 2,400 feet. Then it extends up along the northern side of Barclay creek, crosses that creek and again swings northwesterly along the north side of Index mountain ridge and, at an elevation of about 2,300 feet, again swings south around that ridge and crosses the Great Northern Railroad about one mile above Baring. The eastern boundary of this belt extends south from the north fork of the Skykomish along the valley of Howard creek to Conglomerate mountain and from there swings easterly outside the limits of the map. Between the headwaters of Howard creek and the headwaters of Trout creek, it is separated by a mass of granodiorite. The contact between the two extends along the direction of Trout creek to its head and thence down the valley of Eagle creek, which drains into Beckler river outside the limits of the map.

In the western part of the Index district an outcrop of this same metamorphic rock enters the region from the west in the vicinity of May creek and crosses the Skykomish below Reiter. From there it extends southerly across Anderson creek and along the base of West Index mountain, passing across the south boundary of the map in section 32, Tp. 27 N., R. 10 E.

GENERAL DESCRIPTION.—On account of the extreme complexity of this formation, no attempt will be made to subdivide it. The formation as a whole consists of quartzites in various stages of metamorphism intercalated with schists, slates, crystalline limestones, and cherts, together with metamorphosed interbedded lava flows.

The quartzites are in places massive and nearly white in color, occasionally having a sugary appearance. Other phases are massive and dense and have a dark color. Occasionally narrow bands are composed of fine grained pebbles which have been drawn out in lenticular fashion, while still others are conglomerates composed of chert and igneous pebbles but extensively metamorphosed and fractured subsequent to metamorphism. These quartzite layers range in thickness from 500 feet to narrow bands less than one inch in thickness. Occasionally belts extending across country are composed of alternating layers of quartzite and schist having a thickness ranging from one-half inch to three inches which have been twisted and contorted and faulted and appear as though tied into knots so that in one square foot of area individual layers will be doubled upon themselves four or five times. This appearance is most pronounced near the contact with the granodiorite where metamorphism has been most active. On Barclay creek high steep bluffs are exposed where this type of twisting may be well observed. Other phases of this quartzite are extensively fractured and filled with small gash veins of quartz seldom over an inch in thickness and intersecting in all directions and sometimes composing more than one-half of the bulk of the rock. In the western part of the district, near May creek, this formation is exposed. It consists largely of dark gray fine grained quartzite with a smaller amount of twisted banded rock.

THICKNESS.—Because of the great disturbances which these rocks have undergone it is difficult to estimate their original thickness. An examination made of this formation in the region between Trout and Barclay creeks, and on the ridge extending westerly from Mount Index, indicates a minimum thickness of at least 10,000 feet. Three-fourths of this total, apparently, is represented by quartzite and the remaining fourth is composed of slates, schists, metamorphosed interbedded volcanic flows, crystalline limestone, and conglomeratic quartzite.

CORRELATION AND AGE.—No direct evidence has been found within this district to determine the exact age of this formation. No fossils have been found in place and any which may have existed have been completely destroyed by metamorphism. On the trail leading up May creek near the power house of the Copper Bell mine, pieces of float slate and quartzite may be found. Several of these contain fossil crinoid stems. Whether these were derived from a part of the metamorphic series could not be determined. The underlying country rock in this vicinity is composed of a dense, extremely metamorphosed phase of quartzite, but the float specimens had not been very badly altered. The presence of the fossil crinoid stems, if derived from this formation, indicate the Carboniferous age. Studies made to the north in the valley of the south fork of the Stillaguamish river reveal the presence of similar rocks which seem to extend areally from Mount Pilchuck southeasterly to the Index district. Limestone lenses occurring in that quartzite series on the north bank of Mount Pilchuck contain large numbers of fossil Foraminifera of the genera *Fusulina* and *Orbitulina*. The presence of these organisms suggests the Carboniferous age. The general similarity of this entire metamorphic series in composition and general appearance resembles very closely that of the Cache creek formation in British Columbia,* which is known to be of Carboniferous age upon fossil evidence. Although no direct evidence can be given which will definitely correlate this formation with the Carboniferous, yet on the basis of the indirect evidence just mentioned, it will be provisionally assigned to that period.

GRANODIORITE.

Areal Distribution.—As may be readily seen by referring to the accompanying geological map, outcrops of granodiorite constitute by far the larger part of the areal geology within this district. This same formation is widely distributed throughout the Cascade mountains, where it forms a prominent part of the surface outcrops in the vicinity of Mount Stuart, and from there northward to the British Columbia boundary. In many places it is covered over by older metamorphic rocks, into which it has been intruded, and by later volcanic and sedimentary rocks which were laid down upon it. Wherever these have been removed by erosion the granodiorite forms the surface rock. Within the Index district this formation occupies an area of approximately 60 square miles. It makes up the larger part of the western portion of the Gunn peak mountain mass. On the south side of the south fork of the Skykomish river, it forms a belt about one mile in width and eight miles in length, lying parallel to the valley and is overlaid by the older metamorphic and later volcanic rocks. On the north side of the Skykomish river it comprises nearly all of the area within the limits of the district with the exception of a narrow belt near the mouth of Hogarty and May creeks and a small area near the mouth of Silver creek. Several smaller areas of it outcrop in the eastern portion of the district between the north fork of Trout creek and Merchant's peak, and also on the eastern side of Howard creek. Considering the Index district as a whole, the granodiorite occupies the central portion and is flanked on the east, south and west by metamorphic, volcanic and sedimentary rocks.

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*Annual Report Geological Survey, Canada, New Series, Vol. 7, 1894, pp. 37B-49B.

PETROGRAPHY.—This formation varies much in general appearance in different parts of the district and is locally referred to by the miners as granite. The most typical phase of this rock is well exposed in the Soderberg quarry, about one mile west of Index. The entire mass is here seen to be uniform in character in contrast to the mottled appearance which it possesses in many other parts of the district. Specimens collected from different parts of the quarry show a uniformity in texture, mineral composition and color. Megascopically the rock is holocrystalline, medium grained, dense, of a light gray color and breaks in large blocks with a slight tendency to a conchoidal fracture. When carefully examined the hand specimens are seen to be composed of light colored feldspars, hornblende, and varying amounts of biotite and quartz. Occasionally small crystals of apatite may be seen. A more detailed study of the feldspar crystals proves them to be plagioclase with only a very small amount of orthoclase. When examined microscopically these specimens are found to be composed of about 40% plagioclase, 10% orthoclase, 30% hornblende and biotite, and 20% of quartz, together with occasional crystals of apatite and titanite. The quartz crystals are distinctly allotriomorphic and show the usual low interference colors and the presence of many gaseous inclusions. The plagioclase crystals, when fres are generally allotriomorphic but occasionally hypidiomorphi and generally show well-defined albite twinning lamellae. large number of crystals were chosen, which were cut as near as possible normal to the clino-pinacoid, and measurements we made upon them. The symmetrical extinction angles whi were obtained yielded values ranging from 19° to 23°. The values indicate a soda-lime feldspar having a chemical composition of approximately Ab_6An_4. Studies made on interferenc figures show the mineral to be positive, which, together with it chemical composition, identifies it as andesine. In many specimens these crystals are extremely altered and seem to be composed of clouded patches in which faint traces of albite or Carlsbad twinning may be seen. These alteration products consist largely of kaolin, calcium carbonate and quartz. The orthoclase is generally found in very small amounts and occurs in medium size allotriomorphic crystals commonly showing Carlsbad twinning and nearly always, even in the fresher specimens, some alteration. Hornblende occurs fairly abundant and can be easily recognized by its dark brown color, intense pleochroism and well defined prismatic cleavage, which upon basal sections is always found to intersect at angles of 124°. Most of the crystals have a tendency towards idiomorphism, but the crystal outlines are seldom sharp and distinct. Extinction angles measured on the clino-pinacoidal section between the C-axis and the axis of elasticity gave values ranging from 18° to 20°. These crystals are commonly altered to a dark, opaque material composed of chlorite, biotite, and a little magnetite. Biotite occurs in small amounts and can be recognized by its basal interference figure and nearly hexagonal outline. It is dark brown in color and generally more or less altered. Megascopically it can always be distinguished from the other minerals by its pronounced basal cleavage.

Among the accessory minerals are found small amounts of augite of the pale brown variety occurring in small but fairly well developed crystals and showing no pleochroism. Occa-

sional slender prisms of apatite and zircon were noted. These minerals are nearly idiomorphic and the latter can be at once recognized by its very high index of refraction.

The above description indicates a rock of intermediate chemical composition and the presence of the andesine variety of plagioclase together with the very small amount of orthoclase places it in the diorite family. The presence of a considerable amount of quartz indicates an acid phase of the diorite or what is generally known as quartz-diorite or granodiorite.

In other parts of the district this granodiorite varies very much in character. About five miles northeast of Index in the vicinity of the Ethel Consolidated mine, it is characterized by the presence of many basic secretions in the form of ovoid or spherical patches scattered through the rock. When examined under the microscope these are seen to be composed largely of hornblende and biotite to the exclusion of the lighter colored minerals. These dark patches range in size from one square inch to ten square feet or more. Their origin is believed to be due to the segregation of the more basic elements at a number of centers in the molten magma just prior to solidification, resulting in the crystallization of the more basic minerals about those centers. The lighter colored portions of the granodiorite also vary in texture and in the varying proportions of the constituent minerals. Sometimes biotite predominates as the most important essential mineral. In other places hornblende predominates and occasionally both are almost entirely absent and the rock is composed chiefly of plagioclase and quartz. At times the rock is slightly porphyritic and seems to be composed of a granular ground-mass made up of allotriomorphic crystals of plagioclase, quartz and hornblende, with larger, slightly hypidiomorphic crystals of the same mineral embedded in it. This phase is more common in the near vicinity of the overlying metamorphic rocks, as may be seen on Barclay creek and in the smaller intrusive masses on Howard and Lost creeks. In the mine workings on the Merchant group on the upper portion of Trout creek, small, isolated, irregular shaped masses of granodiorite occur within the metamorphic rock in a zone about five hundred feet in width and extending along the granodiorite-metamorphic series contact. Specimens taken from these small intrusions represent wide variations in mineral composition. Some are very coarse grained and contain a large proportion of hornblende and biotite, while others are finer grained and are made up almost entirely of plagioclase and quartz. The same is true near the contact in the main tunnel at the Copper Bell mine in the western part of the district. On the south side of the Skykomish along the north slope of Mt. Persis, at an elevation of 1,700 feet, this rock has a reddish to bluish tinge and is found upon microscopic examination to contain a small amount of nepheline, with very little quartz, which indicates a closer relation to the syenite family than to the diorite. At first glance these rocks might appear to belong to two distinct intrusive masses, but upon a careful examination in the field this phase seems to be only a differentiation from the granodiorite proper.

CONTACT RELATIONS.—Along the contact between the granodiorite and the Gunn peak metamorphic series many interesting contact relations may be seen. On the divide between Barclay and Lewis creeks the metamorphic quartzite and schists stand out in bold, crag-like fashion and at an elevation of about 3,000 feet are found to lie in contact with the underlying granodiorite. Specimens collected on this contact in a zone about six inches wide, show the development of large crystals of biotite and muscovite, some of which are over eight inches across. These are chiefly developed in the granodiorite, but lie directly in contact with the metamorphic rocks. Biotite in smaller amounts is also developed in the fissures and vein fillings in the quartzite at some distance from the main contact. The contact line is often sharp and distinct. In the locality just mentioned the metamorphic rocks which consist largely of banded and contorted quartzites having a gneissoid appearance, stand with their stratification planes nearly vertical, and the plane of contact with the granodiorite normal to their strike. Locally the direction and pitch of the plane of contact varies considerably, but in general the metamorphic series dip away from the granodiorite. In a zone lying in the metamorphic series and extending more than 1,000 feet from the granodiorite contact there have been developed irregular scattered crystals of garnet, epidote and hornblende. This may be well observed on Uncle Sam creek from a point at an elevation of 3,200 feet up to the summit of the ridge. In other places, as on Lost creek, the metamorphic quartzite seems to have been considerably shattered, thoroughly impregnated with the more acid phases of the granodiorite magma and then re-cemented by it.

GRANODIORITE APLITE.

Dikes of this rock are quite generally distributed throughout the Index district. It is a light colored, fine grained rock, which is sometimes hard and vitreous, resembling fine grained quartzite. More often it is composed of very small crystals, of quartz, andesine and orthoclase, with some biotite and hornblende. Some of the narrower dikes have a very little hornblende and biotite, or even none at all. These dikes have no general direction and vary in width from one inch to over one hundred feet. The walls are always sharp and well defined and the rock is chemically more acid than the granodiorite. Oftĕn in the field it might be mistaken for quartzite. The majority of the outcrops are so small that they have not been represented on the geologic map. It is generally much more resistant to weathering than the granodiorite and stands out comparatively fresh while the latter is more or less altered.

These intrusions are presumed to have been nearly contemporaneous with the Index granodiorite, and to represent more acid differentiations from the deeper part of the magma which have been drawn up into cracks formed in the roof of the partially consolidated batholith. These cracks are supposed to have been formed by contraction of the roof at the time of solidification. The vein fissures cut through these the same as they do the granodiorite.

ANDESITE PORPHYRY DIKES.

These intrusive rocks are found on Howard creek and on the divide between that creek and Trout creek. They are irregular in shape, and have a general east-west trend. In many places they cut up through the granodiorite and metamorphic series in narrow intersecting dikes so that it is impossible to represent them upon the map. One dike lies on the east side of the canyon near the workings of the Co-operative mine. About three miles above the mouth of the creek it forms a part of the west side of Spire mountain and has given rise to boulders of tremendous size, which have come down from the mountain side. It is a dark gray medium grained rock and ranges in structure from granitoid to porphyritic. Under the microscope it is seen to be made up of feldspar ranging in chemical composition from basic labradorite through bytownite. In several slides, acid anorthite was found. The dark minerals are hornblende with enstatite and augite. These crystals are generally subhedral, but often distinctly idiomorphic. In the more porphyritic varieties, the groundmass is composed of small granitoid crystals of labradorite and bytownite with grains of augite and small crystals of hornblende.

This rock is older than the Howard arkose series and may possibly belong to the early Miocene, although no definite statement can be made to that effect.

WEST INDEX ANDESITIC SERIES.

AREAL DISTRIBUTION.—Rocks grouped in this formation outcrop to the southwest of Index in the high mountain ridges forming Mount West Index, and Mount Persis. They cover about four square miles of area within the district and rest unconformably upon the Index granodiorite and the Gunn peak metamorphic series. They outcrop about one-half mile south of the Skykomish river below Reiter, at an elevation of 1,400 feet. From there the contact swings southeasterly across Anderson creek up to the base of Mount West Index at Lake Serene and then passes across the south boundary of the map in section 32.

GENERAL DESCRIPTION.—The rocks composing this formation consist of a complex mass of intercalated layers of fine grained andesitic breccias, conglomerates, and badly altered lavas. The base of the series is exposed at the base of West Mount Index at the level of Lake Serene (2,050 feet). They rest upon granodiorite and quartzite and dip away to the southwest at an angle of about twenty degrees. The total thickness of the series is between twenty-five hundred and three thousand feet. The rocks are gray, but often have a greenish tint. To the naked eye, they closely resemble andesite flows, although many specimens appear to be made up of angular fragments of andesitic material less than one inch in diameter. The texture of this variety can only be detected by careful observation, and they seem to be flow breccias. Other beds are found to contain fragments of quartzite and granite, indicating their partial sedimentary origin. The lavas are medium to fine grained, gray and phenocrystalline. Small lath shaped feldspars with larger crystals of augite lie scattered about in a darker fine grained groundmass.

When subjected to microscopical analysis, many of the specimens which appeared to be lavas, were found to contain many angular and partially waterworn fragments of quartzite, together with re-cemented tuff and andesite. Those specimens which could be classed as lavas, contained phenocrysts of labradorite and augite, embedded in a fine grained groundmass composed of microlite laths of acid labradorite and augite. Occasionally hornblende and enstatite phenocrysts could be determined.

The members of this series grade into each other, but the larger part of the formation is composed of andesite lava.

CORRELATION.—The age of this series of rocks cannot definitely be stated. No fossils occur in it. In some investigations carried on by the writer in the Puget Sound basin and in the western foothills of the Cascades, about ten miles west of the Index district, lavas similar in general appearance and composition rest beneath Oligocene marine fossiliferous beds and above the Eocene brackish water beds. The areal distribution of these were traced eastward towards Mount Index, but not to it. It is quite possible that they are a part of the same formation and if so the age can be set down as late Eocene. It is also possible that the West Index formation may also be of the same age as the Howard arkose formation, but sufficient evidence is not available to make such correlations at the present time.

HOWARD ARKOSE FORMATION.

General Description.—This formation consists of from five to seven hundred feet of coarse, angular arkosic conglomerate with interbedded tuffs, lavas and andesitic breccias. The basal formation is arkosic in character and chiefly made up of small and large angular and rounded boulders of granodiorite, quartzite, chert and lava, embedded in a matrix composed of fine sand grains and volcanic ash. The boulders range in size from less than one inch up to two feet. An excellent exposure may be seen in a cut on the west side of Howard creek, just below Howard lake. Near the middle of the section small lenses less than five feet in thickness of andesitic tuff and lava are interbedded and lie nearly horizontal. Above this a large per cent. of the boulders are composed of andesite and in places the formation becomes an andesitic breccia. On the divide between Howard and Trout creeks, on the ridge leading up to Conglomerate point, the top of this section may be seen. It is composed almost entirely of andesitic breccia. Examinations of thin sections of this rock show the presence of phenocrysts of labradorite, augite and hornblende embedded in a fine very much altered groundmass composed of small microlites of labradorite and grains of augite.

Areal Distribution.—It is limited in distribution and within the district is known to occur in place only near the head of Howard creek on the divide between that creek and Trout creek, where it forms the knob known as Conglomerate point. It is underlain by granodiorite and quartzite and on the Howard creek side the contact extends up the valley slope diagonally to the divide with Trout creek in a northwesterly direction. It swings around the west side of Conglomerate point and reaches Howard creek again at the lake. It has been folded down into the quartzite and possibly the north side may have been let down into the granodiorite by a small fault.

On May creek, above the Copper Bell mine power house, large angular boulders of float material were found, similar to the Howard creek rock, but a careful search on the mountain sides up to the head of that creek failed to reveal any such deposits in place. There may have been, however, small outlying patches of it which escaped detection in some of the more inaccessible localities, or it may have been brought there by glaciers.

On the ridge forming Mount West Index and Mount Persis, andesitic breccias, arkoses and lava flows occur, which may possibly be the same as those on Conglomerate point. They are undoubtedly similar in origin, but they are quite different in appearance.

CORRELATION.—There is no means of determining the geologic age of this formation in this district, except that it is Tertiary. No fossils of any description could be found. It overlies unconformably the Index granodiorite, the Gunn peak metamorphic series and the basic intrusive dikes on Howard creek.

To the north in the Monte Cristo district, Spurr* has described an arkose formation of Eocene age composed of pebbles of granodiorite with some quartzite and old andesite lava flows. In that district it is the oldest of the Tertiary group. That on Howard creek is undoubtedly much younger, and may belong to the Miocene. It is in places thoroughly stained with copper and occasionally contains disseminations of chalcopyrite and pyrite.

OLIVINE DIABASE.

This rock has been observed at one locality only. It outcrops as a vertical dike about twelve feet wide with a trend of S. 36° E. and cuts across the Great Northern Railway track just below Sunset Falls. It cuts up through the granodiorite.

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*22 Annual Report U. S. Geological Survey, p. 788. 1900.

This rock is black and badly altered. To the unaided eye it is fine grained, dense and breaks with a conchoidal fracture. It is seen to contain very small crystals of pyrite scattered through it. Under the microscope it is found to contain phenocrysts of olivine and bytownite embedded in a groundmass composed of small bytownite laths and augite. The groundmass has the typical ophitic structure and the phenocrysts are generally small.

QUATERNARY.

Deposits of Quaternary age are abundant in the district and consist of extensive accumulations of glacial drift, stream alluvium and talus material.

Glacial Drift.—The glacial dift comprises sand, clay, sandy clays, silts and thick deposits of assorted and non-assorted gravels. To the west of Index in the Skykomish valley, these deposits attain a thickness of 500 feet. To the east they gradually become thinner, but form a veneer over the bedrock formations and over the valley slopes. Along the north fork of the Skykomish river the drift is made up of fine gravel and erratic boulders, strewn over the hillsides to an elevation of more than 500 feet above the level of the river. The same is true on the south fork. Near the junction of these two forks, just south of the town of Index, thick deposits of blue clay overlie the bedrock and this in turn is overlaid by partially stratified gravels and sands. About two miles west of Index along the Great Northern Railway cut, beautiful sections may be seen composed of alternating bands of gravelly sands, clays and washed gravel. Cross bedding is very noticeable as well as minor faults. These bluffs have been formed by the downward cutting of the river.

The present condition of the glacial deposits is to be explained by considering the pre-glacial river channel to have been filled with the same material as now occurs in the steep cliffs, by the action of streams issuing forth from beneath the glacier as it retreated to the east, together with material dropped from the surface of the glacier at its margin as the ice front melted. Later, due to an uplift of the entire Puget

Sound region, the Skykomish river entrenched its channel through this accumulated drift until it reached its present level, leaving as remnants the present glacial bluffs on either side of the river as well as deposits beneath it, which have not as yet been cut into. The materials comprising this glacial drift have been derived in part from the rocks occurring within the district and in part from those around the various streams draining into this river.

ALLUVIAL DEPOSITS.—These deposits are limited to the floors of the larger stream valleys and consist of materials deposited by the streams since the retreat of the glaciers. The materials are gravels, sands and clay, which in some places, as near the town of Index, attain a thickness of 20 or more feet. The main valley of the Skykomish has meandered from side to side through its canyon and deposited a considerable volume of material. In many places quicksand has been reported at depths of fifteen feet. A small amount of placer gold occurs irregularly distributed through this material and was the occasion for the earliest settlements in the Index district.

TALUS DEPOSITS.—These deposits are characteristic of all the valleys within this district. All the high mountain ridges contain talus slopes extending more than half way to the summit of the ridges. This material is formed by the weathering of the mountain masses and the numerous snow slides occurring during the winter season. Thousands of tons of rock are brought down each year onto their slopes. One of the best examples of this may be seen in the valley of Howard creek, where great deposits lie along the slope of Spire mountain and along the eastern slope of Iron mountain. Surrounding all of the high glacial lakes are talus deposits composed of angular blocks derived from the precipitous walls surrounding these former glacial cirques.

STRUCTURE.

Among the more important structural features of the region is a great central mass of granodiorite surrounded by older metamorphic sandstones, shales, limestones and lava flows into which it had been intruded during Jurassic time. The contact plane between the granodiorite and metamorphic series is not horizontal, but varies. In most localities where it could be studied it is nearly vertical and in one place the igneous mass had been partially turned over on to the metamorphics. This was caused by a small local fault. On the upper part of Trout creek on the south side of Headquarters peak near the Merchant mine, this vertical contact is well represented. It is not a fault plane, but distinctly an intrusive contact with occasional apophyses of the granodiorite extending into the quartzites. A few local faults have occurred here, but they are unimportant.

Farther to the west on Barclay creek the contact may again be seen. The quartzites pitch very steeply away from the granodiorite, but farther to the south on the south side of that creek the plane of contact becomes more nearly horizontal.

On the divide between Trout and Eagle creeks, the eastern contact of these same formations may be seen. The intrusive granodiorite underlies the quartzites and the plane of contact dips to the west at an angle of 45°.

This belt of metamorphic rock seems to occupy a trough in the granodiorite with a general north to south direction. This can be accounted for only by an axial downfold. The time of folding cannot be determined, except that it had occurred in part at least prior to the deposition of the Howard conglomerates.

In the southwestern part of the district the West Index andesites rest unconformably upon the Index granodiorites and the metamorphics. They have suffered very little folding and dip at an angle of about twenty degrees to the southwest.

Later structural movements, probably closely associated with the final uplift of the Cascade mountain mass, produced numerous joint planes, the more prominent of which were avenues for ascending mineral bearing solutions to deposit the ores. The joints and fissures fall into several classes with certain directions of strike. The stronger and more pronounced joints have a predominant strike of N. 75° W. in the eastern part of the region and those in the west average N. 45° E.

The minor ones make various angles to these, but they more commonly intersect them at angles of twenty or thirty degrees. The major joints pitch at a very steep angle to the south; the minor ones have no predominant pitch.

GEOLOGICAL HISTORY.

The geological history of the Index Mining District is represented by sedimentation, volcanic extrusions, batholithic intrusions, folding, faulting, uplift, erosion and glaciation. Concerning the paleozoic history of this region, we have no knowledge at all, unless a part of the Gunn peak formation may have been deposited during that time. Throughout the Cascade mountains no rocks have been found which from palaeontological evidence could be definitely assigned to the Paleozoic. On some very scanty and indirect evidence certain rocks within this district are provisionally assigned to the Carboniferous. They are now extremely metamorphosed, but originally represented sandstones, shales, interbedded sandstones and shales, limestones and volcanic flows. These appear to have been laid down in marine waters and to represent sediments deposited in Carboniferous and perhaps Triassic and Jurassic seas, which are known to have been extensive on the west coast of North America during that time. Concerning any movements which may have affected these sediments prior to the intrusion of the great batholith of granodiorite, we have no knowledge. The time of intrusion of this batholith is pre-Tertiary and the evidence is based largely upon fossils collected in the Eocene arkoses described by Spurr in the Monte Cristo region. A part of this same granodiorite mass can be traced to the southward in the Mount Stuart and Snoqualmie quadrangles where it underlies unconformably Eocene sandstones.

The effects of this granodiorite intrusion were to metamorphose the older sediments, producing quartzites, slates and crystalline limestones.

The geological record of the larger part of this district has been completely destroyed by erosion and the deciphering of the history of the region is purely hypothetical.

During early Tertiary times the region to the north of Index as well as to the south, was covered with a series of fresh water or brackish water lakes or estuaries, in which conglomerates and sandstones were accumulating. In the Monte Cristo district these have been described as the early Arkose formation and upon fossil evidence have been placed in the Eocene. In this district a small outcrop of similar material occurs near the head of Howard creek and upon a stratigraphical basis is considered as being a remnant of one of these lakes. The remainder of Tertiary time in the Index region is represented by outpourings of volcanic lava and intrusions of basic dikes. These dikes are found in the Howard creek region in the eastern part of the district and may have been the source of volcanic flows similar to those in the Monte Cristo district which once covered this region, but have since been removed by erosion. In the southeastern part of the district a thick series of volcanic flows of andesite dip off to the west. Their age cannot definitely be determined, but they correspond very closely to a series of andesites which appear to be coextensive and occur farther to the west south of Monroe and underlie the marine Oligocene of the Puget Sound basin.

During Tertiary time this part of the Cascades, in common with the eastern portion, appears to have undergone many physiographic movements which finally resulted at the close of the Pliocene, in the uplift of the entire range as a great deformed dome. This uplift is assumed to have produced a series of structural northwest-southeast warps which determined the present position of the Skykomish and Skagit valleys, as well as the Wenatchee and Yakima on the eastern side of the mountains.

Early in the Pleistocene the precipitation became excessive and the climate colder, resulting in the accumulation of great snow fields with resultant glaciers, which ultimately flowed down the stream valleys to Puget Sound, where they united and together with ice streams from the north, formed a great piedmont glacier. Later these glaciers melted and retreated up the stream valleys, leaving strewn over their former course, sands, clays, and glacial boulders. Their work in the mountains was to accentuate the topography, giving it its characteristic sharp, ragged appearance.

CHAPTER III.

ECONOMIC GEOLOGY.

HISTORY OF MINING.

Prospecting and mining in the western portion of the Cascades in Snohomish and King counties did not become active until 1885. In 1874 the first mining claims are said to have been located on Silver creek, but no further development work was done until 1882, when prospecting began on the north fork of the Skykomish near the mouths of Silver and Troublesome creeks. A trail was cut through from Gold Bar up the valley past the present townsite of Index to Silver creek. In 1890 the towns of Galena and Mineral City were laid out and the first settlement at Index made near the junction of the north and south forks of the Skykomish by Mr. Gunn. This consisted of a small one-story lodging house and store—the nucleus of the present town. About this time rich placers were found and located in the valley of the Sultan basin, and as a result of the excitement there, many claims were staked out along the Skykomish river valley from Gold Bar on the west, eastward to Silver creek. In 1892 the western division of the main transcontinental line of the Great Northern Railway was being constructed from Everett eastward up the valley of the Skykomish to the summit of the Cascades, and about two years later a wagon road was cut through from Index to Galena, partly by the county and partly by the miners. A small station was built on the railway just west of the present site of Index and the town became the natural base of supplies for the surrounding mining camps. Under these conditions, prospecting became active over the entire region and a large number of claims were located. The earliest locations made within this district were on Howard, Lost and Trout creeks. In 1892 Andrew Merchant discovered and located several ledges on the upper portion of

Trout creek and John Wallace several on Lost creek. Later, in 1899, Charles R. Howard located a group of eight claims on a series of east-west veins situated about one mile below Howard lake on Howard creek, and a group of four claims about one mile to the north of the same creek.

During the period from 1897 to 1902 mining activity reached the highest point of development and the majority of the claims of the district were located. On June 19th, 1907, Ezra M. Egbert and Arthur C. Egbert located the Sunset lode claim on Trout creek; John Lewis the Non Pareil on the same creek in the same year; C. H. Gray and L. W. Gray the Copper Bell on May creek, and A. M. Watt and Charles E. Cummings the Gunn Peak claims. Shortly after their location many of these claims were incorporated. In July, 1897, the Sunset claims were incorporated as the Sunset Mining Company and the Copper Bell claims in May, 1897, as the Copper Bell Mining Company. In 1900 the latter was reorganized as the Bunker Hill-Sullivan Copper Mining Company and finally in 1902 as the Bunker Hill Mining and Smelting Company. The Ethel claims on Ethel creek, about five miles east of Index were located in 1900, and incorporated in 1905 as the Ethel Copper Mining Company. In March, 1903, the Non Pareil claims were incorporated as the Non Pareil Copper Mining Company.

During this period of time extensive development work was undertaken and several large ore bodies were uncovered and mined. A surface tram was built from Index up the south side of the north fork of the Skykomish to Trout creek, a distance of nearly five miles, and from there a gravity surface tram for a distance of 1,300 feet extending up the mountain side. Finally the surface tram was continued for one mile to the Sunset mine. Several carloads of ore were taken out and shipped to Index, unloaded at the end of the tram and transferred to the Great Northern Railway freight station and from there shipped to the Tacoma smelter. Much of this was not sorted, which resulted in the shipment of some very low grade ores. The other properties in the district with the exception of the Copper Bell were not connected with the railroad by tram and were compelled to bring any ore to Index which they might wish to ship, by wagon or on horseback. The heavy cost involved in hauling the ore, in bringing it to the railroad and the fact that the average ore was uniformly low grade, made mining at a profit prohibitive. About this time the price of copper dropped to twelve cents per pound and mining activity in this part of the Cascades rapidly declined. During the last six years, development work has been confined almost entirely to the required assessment work. Several properties have been patented and their development has entirely ceased. In general it may be stated that the lack of suitable transportation facilities from the mines to the railroad and the low grade character of the ores are responsible for the present inactivity of mining in this district.

At present the Index Galena Lumber Company is building a wide gauge track from the Great Northern Railway at Index up the south side of the north fork of the Skykomish for the purpose of bringing out timber and it is their intention to extend the line up the river indefinitely. One mile has already been built. With suitable transportation many of the properties, notwithstanding the low grade of ores, could be mined at a profit.

TREATMENT OF THE ORES.

The ores in this district are primarily copper and the silver and gold values which occur in small, but varying amounts are not considered in the treatment of the ores. The total amount of ore which has been shipped to Tacoma and Everett is not large. The general practice has been to sort out the rich ore, sack it and transfer to Index by pack train or wagon and ship from there to the smelters.

Two of the properties have erected concentrating mills and ship the concentrates. The Bunker Hill Mining and Smelting Company constructed a mill which was put into operation in April, 1905. It has a capacity of fifty tons of ore per day and contains a No. 2 Austin gyratory crusher, three sets of rolls, coarse, medium and fine, one Johnson vanner, one Dodd buddle, and three Wilfley concentrating tables, one Calumet and one Montana classifier, one dryer for the concentrates and one Cleveland-Knowles magnetic separator, used for the purpose of extracting the iron from the concentrates. There is a 35-horse-power engine which can be driven either by steam or compressed air. The plant has a present capacity of 50 tons per day, but it is so arranged that by adding tables or rolls it can be increased to 75 or 100 tons.

PRODUCTION.

No reliable estimate can be obtained as to the amount or value of the ore produced in this district. The ores are mainly copper and those which have been shipped out, have been sent to the Tacoma smelter. The mines which have produced and shipped ore are the Ethel, Sunset, Wilbur Index and Copper Bell. Some of the other properties may have shipped small amounts, but no information could be obtained. Ten carloads are said to have been shipped from the Sunset, which is said to have averaged 5% copper. The Ethel mine and the Copper Bell have concentrating plants, but the amount of ore shipped is not known. Two carloads are said to have been packed out from the Wilbur Index mine on horseback and shipped to the smelter.

Many of the properties have ore on their dumps and several have it sacked ready for shipment provided suitable transportation could be obtained. The ores are low grade but several of the mines could be worked at a profit if transportation were available and the extra cost of handling were eliminated.

DISTRIBUTION OF THE ORE BODIES.

Mineral veins are very evenly distributed over the entire district and are found in the granodiorite, quartzite, aplite and andesite porphyry. Since the largest part of the areal geology of the district is granodiorite, the larger number of veins are found in that rock. Observations seems to show, however, that the veins occuring in the metamorphic rocks contain a larger amount of pyrite and a smaller amount of copper ore, than in the granodiorite. Assays made on a large number of samples yield much higher values in silver and gold in the former than in the latter, although none of them run over $4.00 per ton. The richest and largest ore bodies which have been encountered in mining development seem to lie in a curved belt extending in a general east to west direction in the middle of the district. Ore bearing veins occur to the south and north of this belt, but they are neither so wide nor persistent in length as in the zone just mentioned. Those in the south are better developed than those in the northern portion.

CHARACTER OF THE ORE BODIES.

STRIKE.—All the fissure veins in this district do not have uniform direction of strike. One of the most common features, however, is their arrangements in a semi-circle with the convex side facing northward. There are a few of the veins which do not conform to this, but as a rule they are small and of not very great importance. In addition to the fissures which have been mineralized there are many fracture or joint planes, and observations made on the strikes of these show the stronger ones to have nearly the same direction as the more prominent fissure veins. Both the fissure veins and joint planes may be grouped under major and minor directions. The veins conforming to the major directions in the eastern portion of the district have a general strike of north 75° west, as may be seen in the Sunset, Non Pareil, and Howard Creek properties. Farther to the west in the Ethel mine the general strike becomes more nearly east and west and in the western part of the region on May creek it averages N. 45° E. The divergence to the south in the western portion of the district on one side of the arc is much greater than on the other side in the eastern part. In the south and central part in the vicinity of Gunn peak, the two directions of strike bend more sharply and finally become parallel to each other, where each extends north and south. The directions of the minor veins and joints vary considerable, but as far as could be determined the larger number intersect the major ones in the different parts of the district at an average angle of 30°.

PITCH.—The veins in the region of Howard and Trout creeks pitch to the southwest, and on May creek in the vicinity of the Copper Bell mine they are nearly vertical, but occasionally dip to the south at angles varying from 80° to 90°. The minor joint planes have a wide range of dip, but from over one hundred observations taken in different parts of the field, 60% were found to average about 40° to the northeast, north and northwest.

SHAPE.—Many of the veins in this district can be traced for a long distance on the surface, but when tapped at depth are found to become narrower, wider, or to pinch out altogether. Often they seem to vary much in width on the surface. Several ore bodies of this character have been opened up and the ore extracted, and upon examination these are found to be lens shaped. These lenses seem to become narrower above and below and forwards and backwards. They lie in the plane of the fissure vein and are portions of the vein which are much wider than the average and are filled with ore. In many places the wall rocks lie in contact with each other, with merely a thin seam of quartz or clay between them. In such cases the veins are generally considered to have pinched out, but that does not necessarily mean that they will not widen again and become large lens-shaped ore bodies.

INFLUENCE OF THE COUNTRY ROCK ON THE ORES.

The veins in this district lie in granodiorite and quartzite, and the larger number occur in the former. The quartzites contain many veins filled with copper minerals, but as a rule the per cent. of copper is much lower than in the veins in the granodiorite. Pyrite is more abundant as well as gold and silver, although the latter two do not occur in paying quantities. Whether the country rock is responsible for this condition, or whether the solutions which supplied the mineral matter were, cannot definitely be stated. Within the granodiorite belt proper, the country rock seems to have had very little effect on the ores. In many cases ore bodies seem to lie in close proximity to narrow granodiorite porphyry or aplite dikes, but no definite relation between those dikes and the veins could be determined. The width of the fissure zones has partly determined the size of the ore bodies. Observation made on veins in the quartzite and granodiorite indicate that the fissures in the latter are more regular, while those in the former are smaller and intersect one another, which allow the solutions to travel in many diverging channels. This has resulted in the formation of a network of small intersecting seams and in the impregnation of the country rock in the quartzite areas. Many of these low grade veins might be worked if the values were not scattered through so large an area of country rock. The hard and resistant character of this rock renders the profitable mining of many of these low grade ores in the quartzite impossible. The granodiorite is fully as hard to tunnel in, but the ores are generally more concentrated in it.

ALTERATION OF THE COUNTRY ROCK.

Because of the excessive rainfall, rapid erosion and unusually thick covering of vegetation, alteration of the country rock has not extended so far as in many of the dryer and arid mining districts. As a rule the rock is nearly fresh and unaltered at the grass roots. In the fissure zones, however, the conditions have been such that alteration has extended for considerable depths, due to downward percolating surface waters. Below the zone where these waters have been active, heated waters from another source have affected the wall rocks. These solutions were those which originally carried the mineral matter from some deep underlying magma to the fissure zone, and in ascending in them precipitated part of the mineral salts, and chemically acted upon the more soluble mineral in the wall rock, and also in the crushed and softened fragmental rock in the fissures. Wherever open fissures existed, they were filled with mineral, but where they were choked up, the solutions in permeating through them dissolved the more soluble portions and replaced them with ore or silica. These solutions have travelled through the wall rocks as well as through the fissures proper, with the result that the former are often very much altered and impregnated with sulphides and silica.

To a certain extent this has been partly responsible for the size of some of the ore bodies. The ore body in the upper workings of the Ethel mine has apparently been formed in this way. It is probable that the portion of the fissure vein representing this ore body was originally wider than the average portion of the fissure, allowing the solutions more freedom to circulate, but in places the character of the gangue indicates that this broad portion of the fissure must have been nearly filled with crushed granodiorite. As the solutions travelled upward through this zone they seem to have extended out into the wall rock also, and the vein resulting from this method of ore deposition must be partly considered as a fissure and partly as a replacement vein.

The process of alteration in the granodiorite involves the breaking down of the feldspar, the extraction of potassium, sodium or calcium, and the formation of kaolin. In many cases the wall rocks do not show any appreciable alteration, even in the near vicinity of the vein. In other cases they are thoroughly decomposed and more or less altered for a distance of one hundred feet or more from the vein. As a rule, in the distinct fissure veins which are narrow and filled with banded ore, the wall rocks are not badly altered, but when the ore bodies are large the solutions have been much more active and as a result the country rock is altered for a long distance away from the walls. Sometimes the alteration of the wall rock is so great that it is impossible to distinguish between that and the vein proper. When alteration is noticeable in the walls, small isolated crystals of pyrite, chalcopyrite or bornite are found scattered through it, but seldom in sufficient amounts to consider the wall rock as ore. In many cases silica has been precipitated from these solutions so as to practically re-cement the altered wall rocks. The alteration effects just mentioned are assumed to have been caused chiefly by upward ascending solutions at the time of the original deposition of the ores.

Descending surface solutions have also played some part in the alteration of the wall rocks. One of the most frequent effects of these solutions is the deposition of the calcite and the secondary enrichment of the chalcopyrite to bornite, chalcocite, cuprite and other oxidized copper ores.

MINERALOGY.

The minerals comprising the ores of this district are chiefly chalcopyrite, pyrite and bornite, carrying small amounts of silver and gold. The latter are, however, more intimately associated with the pyrite than with the copper minerals. In addition to the sulphides just mentioned the lead sulphide, galena and the zinc sulphide, sphalerite are occasionally found, but they are unimportant. The gangue minerals are mainly quartz, together with calcite, sericite and very rarely fluorite. The enriched products in the upper portions of the veins are chalcocite and bornite, together with the oxidized minerals; cuprite, malachite and micaceous hematite.

PYRITE.—This sulphide is widely distributed throughout all of the veins in the district. It occurs both in crystalline and massive form. In some places it is disseminated in small grains through both veins and wall rock. In others it occurs as small bands, stringers, or irregular shaped masses. It is light yellow and very often intricately mixed with chalcopyrite with which it seems to be synchronous in origin. As a part of the vein filling, it is more common in the metamorphic rocks than in the granodiorite. It has been altered near the surface to micaceous hematite and limonite.

CHALCOPYRITE.—This is the most common mineral of copper in the district. It is generally found massive and seldom as crystals. Often large masses of it occur several feet in diameter with no impurities, but it is generally associated with pyrite and quartz or disseminated in the wall rocks as small kernels, for some distance away from the vein. It is more common in the deeper portions of the vein than near the surface, where it is often partly enriched, forming bornite.

Bornite.—In several of the mines bornite is the predominant copper ore. It is always more prominent in the upper part of the vein and gradually decreases in depth. When broken it is often found to form a shell around the inner kernel of chalcopyrite, showing the effects of enrichment by downward leaching. In some veins it occurs in pure massive form in bands varying in width from two inches to one foot, and in others in small grains about the size of a pea scattered about in the matrix of crushed granodiorite largely altered to sericite and quartz and cemented by secondary silica derived from solution. This condition prevails in the ore body at the Ethel mine.

Chalcocite.—This mineral does not occur in large quantities nor in all parts of the district. It is more closely associated with bornite than with the chalcopyrite and forms small irregular seams extending through the former. It also occurs in irregular bunches in the sericite gangue of the veins.

Cuprite.—It is found in the upper portion of some of the veins, especially in the surface outcroppings. It is an oxidation product from the original chalcopyrite.

Malachite.—It is widely distributed near the surface, but only as a coating on the other minerals or rocks. It is an oxidation product.

Galena.—This mineral occurs occasionally in all of the veins, but seems to be more prominent in and closely associated with the pyrite veins in the metamorphic series than with the chalcopyrite. It occurs in the form of small isolated crystals and is quite conspicuous in the quartz veins on Lost creek.

Sphalerite.—It is less common than galena but occurs in a similar manner. It is found in small amounts in the veins on the north side of Ethel creek.

Hematite.—It is very common in nearly all of the veins in the district, and occurs near the surface, generally as a capping to the copper veins. It has resulted from the decomposition of the chalcopyrite and pyrite and the oxidation of the iron.

The copper has been taken into solution and carried downwards where it has enriched the unaltered chalcopyrite and resulted in the formation of bornite. Most of the hematite is of the micaceous variety and contains scattered through it small kernels and unaltered irregular shaped masses of chalcopyrite and bornite.

LIMONITE.—It is found near the surface as a rusty mass, coating the quartz or vein material. It has also resulted as in the case of the hematite from the decomposition of the chalcopyrite and pyrite.

QUARTZ.—Quartz is the most common gangue mineral and has resulted partly from the alteration of the crushed granodiorite in the vein, and partly from the mineral solutions from below which brought up the copper and iron sulphides. It is generally massive and is a cementing material for the metallic minerals, but sometimes occurs in well formed, prismatic, pyramidal crystals.

CALCITE.—Calcite is fairly common as a gangue mineral, but seems to be best developed in those veins near the quartzite-granodiorite contact. It is a conspicuous mineral in the veins in the Ethel mine and has formed subsequent to the primary deposition of the ores.

STRONTIANITE.—It occurs in a narrow seam about four inches wide in a vein on the north side of Ethel creek.

HORNBLENDE.—This is a common vein mineral in the near vicinity of the granodiorite-metamorphic series contact. It is abundant on the north side of Barclay creek in the quartzites at the Uncle Sam mine where it occurs in crystals ranging from two millimetres up to five inches in length. With it are associated epidote, calcite, pyrite, chalcopyrite, garnet and hematite. It is also found with the copper ores at the Copper Bell mine, but there it is not far from the quartzite contact.

GARNET.—It occurs in crystals up to an inch in diameter along with hornblende and epidote on the north side of Barclay creek in the quartzite.

Sericite.—It is common in the veins where it has resulted from the decomposition of the silicates in the granodiorite.

Kaolinite.—Occurs in considerable quantities in the veins, especially near the walls, and has resulted from the decomposition of the aluminous silicates forming the veins and walls.

Fluorite.—It was noted at one place only. In the upper portion of the Ethel vein several crystals were found with bornite and calcite in a matrix of decomposed granodiorite partially re-cemented with silica.

Silver.—No mineral of silver was seen. Assays made on quartz containing pyrite taken from Lost creek and Howard creek gave returns of two and five-tenths ounces to the ton. Assays made also upon micaceous hematite samples collected in the Florence-Rae tunnel on the west side of Trout creek gave low values in silver. A larger number of assays gave only a trace.

Gold.—Gold occurs similar to silver and the highest assays obtained were 0.2 ounces to the ton.

GENESIS OF THE ORES.

The ore deposits of this district occur in distinct fissure veins and in veins which are partly fissure and partly replacement. In the eastern part of the district the veins have a general strike of N. 75° W. and in the western a strike ranging from N. 45° E. to N. 10° E. and a nearly constant pitch at a very steep angle to the south. These fissures extend through the granodiorite and Gunn peak metamorphic series as well as a number of later intrusive dike rocks. The ores are chiefly sulphides of copper and iron together with small amounts of gold, lead, and zinc. The gangue material is largely quartz.

These ores are assumed to have been derived from the deeper portions of the earth's crust by the action of ascending solutions under high pressure and temperature. The definite character of these deep seated rocks which supplied the mineral matter and the date of mineralization cannot absolutely be determined.

There seems to be evidence for considering the Gunn peak metamorphic formation as a series of sandstones, shales, limestones, and lava flows which were laid down on the sea floor during the Carboniferous or possibly Triassic or Jurassic times. There seems also to be justification in considering the Index granodiorite as a part of the great granodiorite batholith which is known to have been intruded into the Sierra Nevadas of California and the mountains of Oregon and parts of the Cascades of Washington at the close of the Jurassic period. Within the area of the district we have no known Cretaceous formations and the age of the lava and the conglomerates lying on the margins of the district are not very well known, except that they belong to the Tertiary.

The larger part of the area and the one in which most of the copper ore deposits are located is composed of granodiorite. The question at once arises whether or not that rock was the original source of the ores and also whether they were deposited soon after its consolidation or at some later time during the Tertiary.

To the north of Index in the Monte Cristo district, Mr. Spurr has described the ores and discussed their origin. In that region the Index granodiorite is not exposed at the surface, but lies deeply buried beneath a thick covering of Tertiary sedimentary and volcanic rocks which undoubtedly are in part the equivalents of those which overlie the granodiorite in the east and southwestern parts of the Index district, and which once undoubtedly overlaid the entire district. In the Monte Cristo district, the Tertiary rocks have been fissured and filled with mineral matter composed of pyrite, chalcopyrite, and arsenopyrite, carrying values in gold and silver. These rocks are cut by dikes of tonalites which are chemically and mineralogically closely related to the Index granodiorite, but which are geologically much younger and probably had no connection with that magma. To the south, in the vicinity of Snoqualmie pass, granodiorites of the late Tertiary age are exposed at the surface and it has been suggested that the tonalite dikes in the

Monte Cristo region are small apophyses connected below with a large underlying mass of granodiorite which is part of a late Tertiary batholith. The vein fissures in that district are later than the tonalite and seem to be directly associated with it. The fissures are assumed to have been formed by those mountain making movements which resulted in the uplift of the Cascade mountains into their present position. Because of the intimate relationship of the veins to the tonalite, the ores are considered by Mr. Spurr to have been derived directly from them by circulating solutions and deposited in the fissures. These two districts are less than twelve miles apart and the intervening area contains mineral veins of similar character. The tonalite and Index granodiorite are petrographically similar, and even though the former should occur in the Index district, it would be almost impossible to distinguish it from the older granodiorite.

The Index granodiorite is cut by numerous fine grained granodiorite porphyries, much more acid than the granodiorite proper. They are in the nature of aplites and are assumed to have been intruded while the granodiorite magma was in the process of consolidation. It is possible, but not probable, that they may be the equivalent of the tonalites.

In the Index district the fissure veins cut some of the Tertiary lavas, and hence there seems to be ground for considering the fracturing and jointing to have occurred in late Tertiary time and quite possibly along with that in the Monte Cristo region.

The more prominent veins, as previously mentioned, have definite directions of strike and dip. A large number of observations taken on non-mineralized joint planes show these directions to be closely related to those of the veins and hence are assumed to have been formed along with the vein fissures during Pliocene time. These fissures are often persistent and can be traced for more than two miles. It is presumed that in the process of fracturing much of the rock adjacent to the walls of the fissures was crushed, due to friction. The width of the fissure zones are assumed to have varied from place to place and the fissures themselves to have extended down for great depths as well as upward into rocks which have since been removed by erosion.

The source of the ores may have been the deeper parts of the Index granodiorite, but it seems more probable since the ores were deposited late in the Tertiary, that they were derived from deep seated granodiorite magmas of Tertiary age, genetically associated with the tonalite dikes at Monte Cristo and the granodiorites at Snoqualmie pass. It is also possible that the fissures may in part have been formed by the stresses in the earth's crust produced by the expansion and contraction of this underlying magma in the process of its consolidation together with pressure exerted in the uplift of the mountain mass.

The question now arises whether the ore bearing solutions were given off directly from the magma below or whether we are to assume that this had practically consolidated and cooled and that the solutions represented downward traveling meteoric waters which had come in contact with it and while passing through it under high pressure temperatures, took into solution their mineral content and upon reaching the lower portion of the fissures, traveled upwards, and, under gradually reduced pressures and temperatures, precipitated from solution their mineral content.

It is possible that both processes may have been going on. Insomuch as the time involved in the cooling of a deep seated batholith is conceived to be very long and as gases and solutions would be given from the lower portion long after the roof had consolidated, it is probable that the solutions carrying the ores were derived almost entirely from the Tertiary granodiorite.

These solutions carried silica, sulphides of copper and iron, with some lead and zinc and a small amount of gold and silver. These in general travelled along the major fissures. When the openings were clear and narrow the fissures were filled with solid ore as in the case of the Index bornite vein. Such veins are seldom in this district more than a few inches wide and the walls are never very much altered. Where the fissures were wide and filled with crushed material the solutions had a wider area to circulate through and often extended out into the wall rock. In such cases large ore bodies or lenses were developed and the ore is found scattered in irregular bunches, some of which are of large size embedded in a gangue composed of decomposed crushed vein rock and wall rock re-cemented with silica. Such deposits are partly in the nature of replacement veins. The feldspars and amphibole of the granodiorite adjacent to the vein were altered to sericite and kaolin and the alkalies carried away in solution.

These wide ore bodies or lenses are considered to lie in the plane of the fissure and, in the intervals between the lenses, the walls of the fissures are assumed to be lying in contact. In such places the solutions would have little chance to circulate and hence the vein would be represented by a mere seam of quartz or kaolin with no ore. An examination of the veins of the district shows them to occur exactly in this way.

The primary minerals are pyrite and chalcopyrite. The secondary minerals are bornite, chalcocite, cuprite and iron oxide. The latter are assumed to have been formed by secondary enrichment. The copper-iron sulphide-chalcopyrite has been acted upon by direct oxidation, resulting in the formation of cupric and ferrous sulphates. The latter further oxidizes to ferric sulphate. In traveling downward these attack the unaltered cupriferous pyrite resulting in the formation of bornite and chalcocite, and leaving the iron in the form of an oxide. In some of the veins bornite forms the chief mineral of the ore. It often may be seen as a shell surrounding irregular masses or grains of chalcopyrite which have escaped complete alteration. This is characteristic of certain portions of the ore bodies in the Ethel Consolidated Mines just north of the mouth of Trout creek.

Considering the Index district as a whole, the ore bodies are assumed to occur in lenses lying in the plane of the fissure with barren or nearly barren intervals between. The ore bodies will undoubtedly extend down at least one thousand feet below sea level, and will be characterized by lenses or ore chutes of varying sizes, lying in fissure veins and connected one to another by very narrow seams of ore or entirely barren seams. There is no possible means of determining where these may lie except by drifting on the veins or by the use of a diamond drill. The copper ores are certain to consist of the mineral chalcopyrite, with practically no bornite, but probably with an increasing amount of iron pyrites.

PLACERS.

The placer deposits in this district are not of commercial importance. From 1888 to 1892 many claims were located along the Skykomish river up to and beyond Galena. Considerable work was done near the mouth of Silver creek. Some gold is said to have been taken out, but no information could be obtained as to the amount. Colors can be obtained by panning at almost any point along the river but sufficient values could not be obtained to profitably mine.

The stream valley is deeply filled with glacial drift and overlying this are stream silts and gravels. It is possible that on bed rock underlying the glacial material placers might be found, but even that is not certain. If there were deposits, the expense of mining would be prohibitive because of the great depth. To the north of this district in the Sultan basin, considerable placer gold is still known to exist.

CHAPTER IV.

DETAILED DESCRIPTION OF THE MINES.

GENERAL STATEMENT.

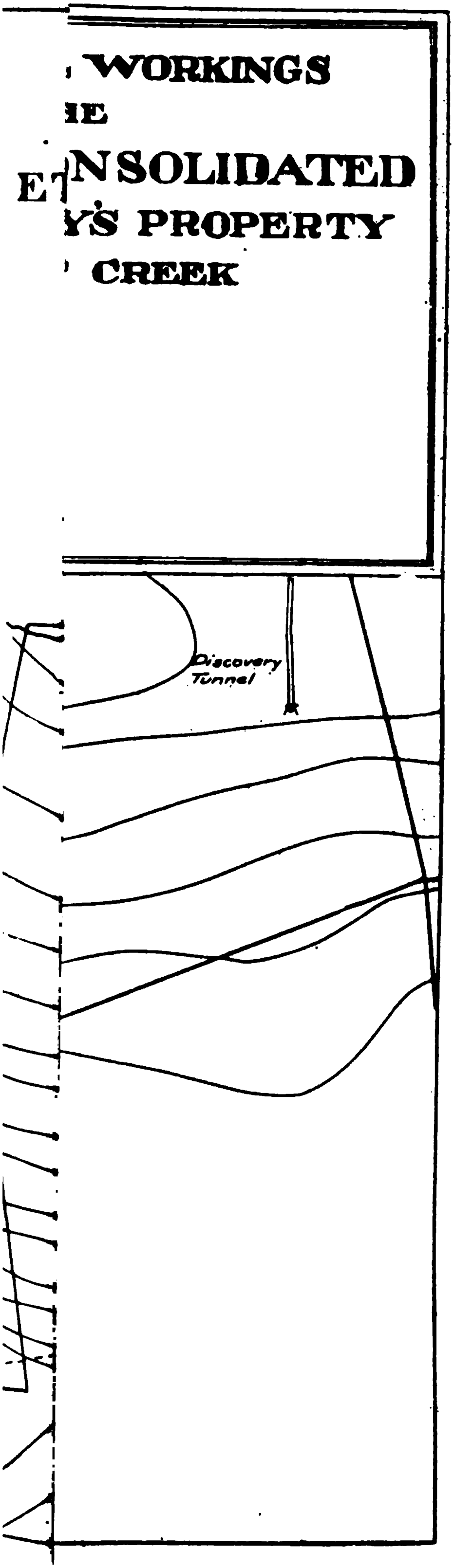
While mapping the areal geology of this district, an effort was made to examine and study the veins and ore bodies in every mine. A number of tunnels were caved and filled with water, and hence inaccessible. There are several hundred claims which are now being held either by assessment work or patent and in addition probably as many more which have been abandoned. Eight groups have been patented. In this report only those properties which are now held will be described. In the claim map accompanying this report, nearly all of these claims have been represented. Where surveys have been made, the claims have been accurately tied into section corners. A part of the others are tied in by tape and compass survey and still others have been platted from data given by the owners. In describing each of these properties, especial attention will be given to the history, development, character of country rock and veins, and the form and distribution of the ore bodies.

SUNSET MINE.

This property, which is one of the largest in the district, is located on Trout creek near its junction with the north fork of the Skykomish river. It is reached from Index by a surface tram road six miles in length, built along the south side of the river. The property is owned by the Sunset Mining Company and consists of thirty-six claims. The first location was made upon the Sunset Lode claim and the Black Bear claim, on June 19, 1897, by Arthur C. Egbert. It was originally incorporated as the Sunset Mining Company on July 8, 1897, by Ezra M. Egbert and Arthur C. Egbert. John McManus became secretary, E. M. Egbert, president, and Nicholas Rudebeck, general manager. The deed was filed on August 2, 1897, by E. M. Egbert. One million shares of stock were issued at one dollar each.

The development work upon this property consists of tunnels, open cuts, trails, buildings and trams. A surface tram road has been built from the mine on Trout creek along that creek to the Skykomish river and from there to Index. A flume has been constructed from the main camp to a point about one and one-half miles up the creek where water is taken directly from Trout creek and carried to the power house for the purpose of running the electrical machinery which lights the mine and buildings. The main camp is situated on the Star claim on the east side of the creek. The underground workings are confined chiefly to the Star, Brown Bear, Black Bear, and Copper King Extension claims, although shorter tunnels and open cuts have been made on the others. The main tunnel has been driven eastward into the hill at a slight elevation above the creek, as a cross-cut from the Star claim into the Brown Bear claim. Six hundred feet from the mouth a drift has been driven on the vein both to the northwest and southeast, the former for a distance of 500 feet, and the latter for about 750 feet. About 420 feet from the intersection of the cross-cut in the right-hand drift going in, an upraise has been driven on the vein for a distance of 80 feet. From the intersection of the cross-cut and this drift, the main tunnel has been driven 475 feet farther and short drifts driven to the right and the left.

About 178 feet above the level of the lower tunnel a second short cross-cut tunnel, opening on the Black Bear claim, has been driven into the hill to the northeast for a distance of 250 feet, where the same vein was intersected as in the lower tunnel. A drift was run on the vein both to the right and left, and in the left-hand drift an upraise was driven to the surface directly on the ore body and a large amount of ore was stoped out and carried by tram to Index and shipped from there to the Tacoma smelter. On the Ravine claim about 300 feet of tunnel has been driven.



WORKINGS
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CREEK
Discovery Tunnel

All of the underground workings are in granodiorite. On the eastern side of this property this rock comes in contact with quartzite and intrusive dike rocks. The veins have a general trend of north 78° west with a pitch of 80° to the east. In the stopes in the upper tunnel the maximum width of the vein was found to 40 feet, but the west wall has not as yet been definitely determined. Towards the surface the ore body becomes narrower as well as in depth. In the lower tunnel it varies from 2 to 16 feet and in places appears to pinch out entirely, leaving the vein simply represented by a zone of crushed and extremely altered granodiorite with a little quartz and a very thin seam of ore. The ore body proper occurs in the form of a lens with its long axis lying in the plane of the fissure and represents that portion of the fissure which is wider than the average and in which the mineral solutions deposited the larger part of the ore bearing minerals. The minerals forming the ore are mainly chalcopyrite, a small amount of bornite, with pyrite and marcasite in a gangue composed of quartz, calcite, and altered granodiorite. Some alteration of the original ore has occurred, resulting in the formation of chalcocite and cuprite. The country rock on either side of the vein proper is much altered and the biotite appears to be partially replaced by chalcopyrite and bornite.

NON PAREIL MINE.

This property consists of 32 claims located on the east side of Trout creek above and southeast of the Sunset group and about six miles from Index, from which place it is connected by a trail and surface tram road. These claims were originally located in 1898 by John Lewis. On March 6, 1903, they were incorporated by Nicholas Rudebeck, Rachel Rudebeck and George P. Rossman, as the NonPareil Consolidated Copper Company, with a capitalization of $1,000,000 at one dollar per share.

The underground development on this property consists of 1,700 feet of tunnel, together with open cuts, trails and cabins. A tunnel has been driven into the hill on the Imperial claim for a distance of 700 feet and about 550 feet from the mouth a cross-cut has been driven through the Imperial into the Blue Mud for the purpose of intersecting the Blue Mud lode, which occurs as a vein higher on the surface. Several smaller branch tunnels have been driven from the main tunnel. Other tunnels, part of which were inaccessible, have been driven on the other claims. The country rock on the Imperial and Blue Mud workings is granodiorite. The ores occur in fissure veins, having a general direction of about north 70° west with a vertical pitch, and consist of chalcopyrite, bornite and pyrite in a gangue composed of disintegrated and altered granodiorite partially re-cemented by quartz. The vein varies in width, ranging from one to seven feet. Three small parallel veins were intersected in the cross-cut tunnel within a distance of 200 feet from the main tunnel, but do not contain exceptionally high grade ores.

To the east on the New Lone Star, Imperial and Blue Mud extension claims, numerous open cuts and short tunnels have been made. The minerals are chalcopyrite, bornite and chalcocite.

The country rock is a part of the Gunn peak metamorphic series and is cut by a series of basic igneous dike rocks. No definite relation between the veins and country rock could be determined.

ETHEL CONSOLIDATED MINE.

Several of the claims belonging to this property were originally located in 1900. Late in August of the year 1903, the W. J. Bryan, Excelsior No. 2 and Excelsior No. 3 were located and in February, 1904, an amended location was made on the Ethel No. 1, Ethel No. 2, the Excelsior, Excelsior No. 1, Excelsior No. 2, Columbus, John D., Scotty, W. J. Bryan and the New Home claims. In December, 1905, these were incorporated as the Ethel Copper Mining Co., which later became the Ethel Consolidated Mining Company.

This property is situated in sections 34 and 35, Range 10 E., Tp. 28 N., about five and one-half miles northeast of Index on the north side of the north fork of the Skykomish river and is reached from that town by a wagon road extending up along the river. The development work consists of a wagon road extending from the main camp to the county road just mentioned, of buildings, including bunk houses, offices, and a large concentrating plant, which has been described in a previous chapter, and approximately 3,200 feet of tunnels, upraises and shafts. Electric power is developed from Ethel creek for running the concentrating plant and lighting the mines and buildings.

There are three main tunnels. The lower and longer one is at an elevation of 1,250 feet and has been driven in on the vein for an approximate distance of 2,000 feet. About 1,000 feet from the mouth an upraise has been made on the vein for about 100 feet and much of the ore stoped out. The tunnel opens on the Edwards claim, extends through the Edwards No. 2, the New Home, and ends in the Ethel No. 2. The second tunnel opens near the level of Ethel creek at an elevation of 1,800 feet and extends south into the hill as a cross-cut for a distance of 500 feet, where it intersects the vein. At the point of intersection a drift has been driven to the west for a distance of 500 feet and an upraise made on the vein for 200 feet, where it connects with the level of the drift on the upper cross-cut tunnel. To the east of the intersection a drift has also been driven about 250 feet.

The upper cross-cut tunnel, opening at an elevation of 2,050 feet, has been driven to the south for 225 feet where it intersects the same vein, drifts have been run both to the east and to the west and the ore has been stoped out for about 100 feet above the level of this drift toward the surface. A short distance to the east from this tunnel, and about 50 feet above it in elevation, another cross-cut tunnel has been driven in about 300 feet, but the vein, apparently, has not been reached. Numerous shorter tunnels and open cuts exist on the several claims. The ore from the upper cross-cut tunnel is dropped to the level of the lower cross-cut tunnel through an ore chute and from there, together with the ore from the latter tunnel, is transferred to the level of the main lower tunnel by a tram railway which carries it to the concentrating plant.

The country rock is granodiorite, cut by occasional narrow dikes of granodiorite porphyry of a later age. The general trend of the vein is north 75° west, with a very steep pitch to the south. It is a fracture or fissure zone in the granodiorite with the partial replacement of the ground-up country rock in the fissure with bornite, chalcopyrite, quartz, calcite, and a small amount of fluorite. Near the eastern end of the lower main tunnel the vein is only a narrow seam filled with gouge material and a small amount of bornite and iron sulphide. Farther to the west, about 1,000 feet from the mouth of the tunnel, the vein widens out and forms a part of a large ore lens which is more heavily impregnated with bornite. The ore is not evenly distributed throughout the lens but is scattered in irregular bunches, yielding a considerable amount of low grade ore. At the face of the lower cross-cut tunnel in the west drift, the same vein is again found. It is about 12 feet wide and has been partially stoped up to the level of the tunnel above. From the level of this upper tunnel, it has been stoped still further up for a distance of 100 feet. The vein is about 20 feet wide and occurs in a soft, crumbly gangue composed of decomposed granodiorite, resembling coarse arkosic sand. This is partially cemented by quartz and the mineral is almost entirely bornite with a very small amount of chalcopyrite and considerable pyrite. Calcite also occurs in places. The ore is not evenly distributed through the vein and in many places is of too low grade to be commercially mined. Many scattered bunches are, however, exceedingly rich.

KITTANNING MINE.

This mine consists of four claims known as the Cuprite, Wonder, Copper Pick, Copper Idol and Copper Bar, which were originally located in 1900, but a re-location was made in July, 1909, by Judson C. Hubbard, of Seattle. The property is located about seven miles from Index on the north slope of the divide between Trout and Lost creeks. It is connected with Index by one trail which extends from the Sunset surface tram at the Trout creek crossing eastward along the south side of the north fork of the Skykomish river and by another trail which follows the Index-Galena wagon road to a point seven miles from the town, crosses the river and proceeds up the mountain to the mine. The development work consists of a tunnel at an elevation of 2,000 feet, driven in on the vein in a general direction north 75° east for a distance of 525 feet. The country rock is entirely granodiorite and the vein represents a zone of fracture or fissuring in this rock, filled with crushed granite much altered and partially re-cemented with quartz containing chalcopyrite, bornite, pyrite and a little chalcocite. Near the face of the tunnel the vein is five inches wide, but about 300 feet from the mouth of the tunnel it widens to two feet five inches where a short upraise has been made. Although narrow, the vein consists at this point of high grade ore which pinches on either side.

MERCHANT MINE.

This property consists of twelve claims, situated on the upper portion of Trout creek about four miles from its mouth. The majority of these claims were located in 1891, 1892, 1893 and 1896, by Andrew Merchant. In 1897 a part of them were bonded to M. E. Downs, who installed an air compressor and built a bucket tram about 2,800 feet in length from the main tunnel on the west side of Trout creek to the main camp on the creek. This property is at present owned by Robert Merchant, of Index.

The development work consists of about 1,700 feet of tunnel in the main workings just above the camp on Trout creek. In the Ore Or No Go claim there are 150 feet of tunnel; on the Fred P. claim, 500 feet; and on the Big Goat, 175 feet of tunnel. These are all connected by trails to the main horse trail on Trout creek. The country rock is granodiorite, together with metamorphic slate and quartzite. In the main tunnel just above the camp, quartzite occurs for a distance of 500 feet from the mouth. At that point it is replaced by a belt of granodiorite for a distance of 250 feet and then the metamorphic rock reappears. The main contact of the Gunn peak metamorphic formation on the south, and the granodiorite on the north, extends nearly east and west along the south side of Headquarter peak, with a nearly vertical pitch. This contact is very close to the mine workings, is distinctly intrusive, but somewhat locally disturbed by minor faulting. On the Fred P., Big Goat, and Ore Or No Go claims the country rock is entirely granodiorite. In the mine workings of the main tunnel just above the camp on Trout creek the wall rocks are hard, dark colored quartzite, having between them a fissure vein composed of crushed rock re-cemented with quartz and containing chalcopyrite and pyrite, which has a general direction of N. 10° W. The vein is narrow and seldom over five feet in width and the ore is usually distributed throughout the gangue. In the south workings of this same property, downward leaching has left behind a considerable amount of micaceous hematite containing small kernels of chalcopyrite and bornite scattered through it.

On the Big Goat claim the vein trends approximately north 80° west, with a nearly vertical pitch. The width varies, but averages about four feet. There is a tendency to banding which may be seen in the alternate layers of quartz with chalcopyrite, pyrite and bornite. The granodiorite on either side of the vein is more or less impregnated with pyrite and chalcopyrite, but not sufficient to constitute even a low grade ore. On the Fred P. claim the vein is in places 12 feet wide, similar in character to the one just mentioned, containing chalcopyrite and pyrite, but not heavily mineralized. The vein in the Ore Or No Go tunnel varies in width from two to eight inches, stands vertical between granodiorite walls and contains chalcopyrite and pyrite cemented by quartz.

HOMESTEAD MINE.

The eleven claims belonging to this group are situated on the west side of Trout creek about two miles above its junction with the Skykomish. These were located in 1904, 1905, 1906 and 1909, by Peter McLain and incorporated on August 3rd, 1909, as the Homestead Copper Company. Short tunnels have been opened on each and the ores, consisting of chalcopyrite and pyrite, are entirely in granodiorite.

COOPERATIVE MINE.

This is located on Howard creek about eleven miles east of Index, from which place it is reached by wagon road up the north fork of the Skykomish for a distance of eight and one-half miles. A wire rope cable and cage extends across the river to the mouth of Howard creek, and from there a good horse trail follows up the creek to its head at the lake. There are two groups of claims on this property, a lower and an upper one. The former consists of four claims; the Phoenix, Vulcan, Pennsylvania and Keystone, arranged two long and two wide on the east side of the creek about one mile above its mouth. They extend nearly east and west up the mountain side. An upper group of twelve claims is situated two and one-half miles farther up the creek. These extend about N. 75° W. and cross the creek.

These claims were first located in 1897 by Charles R. Howard and later in the same year were sold to the Cooperative Mining Syndicate. For several years following considerable work was done in developing these, but for the last six years only assessment work has been carried on.

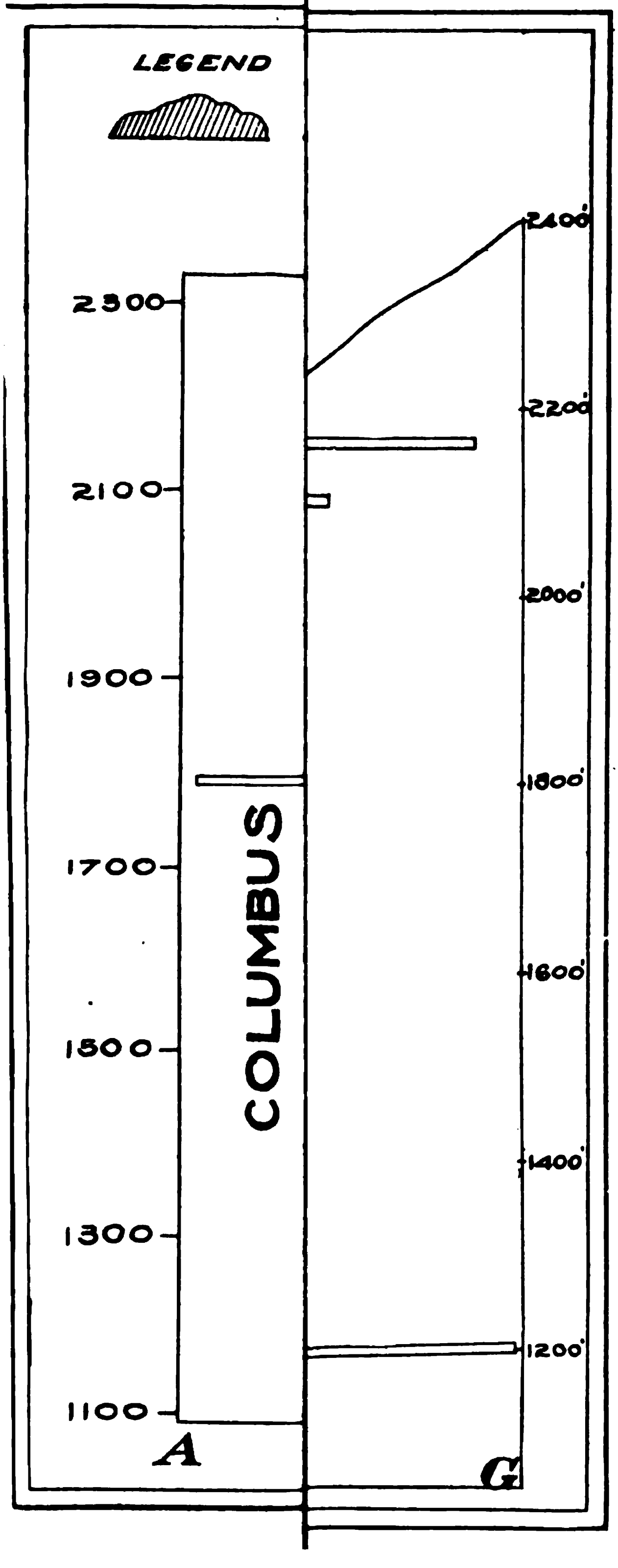
Development work on the lower group consists of two cabins, trails and two tunnels, and several open cuts. The lower tunnel is one thousand feet above the level of the creek on the Keystone claim and has been driven in on the vein for a distance of 180 feet with a twenty-foot upraise. The lower tunnel is a cross-cut 200 feet higher for the purpose of tapping the same vein.

At the upper group several cabins have been constructed and several hundred feet of tunnels driven. The veins are in quartzite and granodiorite and trend about N. 75° W. Near the lake a shaft has been sunk near the contact and samples collected here gave values in gold ranging from one to six dollars per ton. Chalcopyrite and bornite occur in all the veins, but pyrite predominates.

LOST CREEK MINE.

The Lost Creek property consists of several claims situated along Lost creek about nine miles east of Index. They are reached by a wagon road extending up the north fork of the Skykomish river and by a wire rope tram crossing that river to the mouth of Howard creek and thence by trail. Several claims were located here in February, 1897, and operated by the Lost Creek Mining Co. Later these changed hands several times and were finally relocated and at present are owned by E. J. Wallace and C. L. Byron of Seattle. The claims are known as the Hidden Treasure, Iron Mountain, Fraction, Mammoth, Parrott, Rudyard Kipling, Rudyard Kipling No. 1 and No. 2, East Kipling, Roosevelt and Rustic. They lie to the east of the granodiorite mass in a metamorphic belt consisting largely of quartzite which is cut by later intrusions of basic igneous rock.

On the east side of the creek at about 3,800 feet elevation, is located the Roosevelt tunnel, which is 60 feet in length and lies in quartzite. Above this is the Upper Roosevelt. The rock is badly shattered and fractured and no well defined vein could be determined, although disseminations of chalcopyrite, bornite, chalcocite, pyrite and hematite occur in the rock. Higher up on the same side of the creek is another tunnel known as the Marion, located in January, 1909. This is in quartzite and the ores are similar in character. On the west side of Lost creek at an elevation of 3,800 feet, a tunnel has been driven into the hill fifty-seven feet on a vein trending north 45° west for a distance of 85 feet. The rock is a fine grained quartzite and the ore as seen in an open cut on the surface is about eight feet wide and is characterized by quartz,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pretty heavily impregnated with pyrite and containing a small amount of chalcopyrite. Assays taken here gave $4 per ton in gold and 2.8 ounces silver.

UNCLE SAM MINE.

This property is located in section 23, R. 10 E., Tp. 27 N., in the high mountain mass between the north and south forks of the Skykomish river, and more definitely, on the south slope of the divide between Lewis and Barclay creeks at an elevation of 3,200 feet. It is reached by trail from both Index and Baring, from the former a distance of four miles and the latter a distance of three miles. The property consists of four claims known as the Zenith, Baring Star, Barclay Bluffs and the Minoka, arranged two in length and two in width and extending north and south just over the ridge into the Lewis creek divide. These claims were located in May, 1897, by Mr. William Cornwall of Index. The development work consists of trails, two cabins, and about 400 feet of tunnel, three of which have been driven in on the vein.

The country rock is mainly a part of the Gunn peak metamorphic series. On the western side of the Zenith and Baring Star claims this quartzite occurs in contact with the underlying granodiorite, where the contact relations can be well studied. About 100 feet up the hill from this contact a tunnel has been driven on a ledge of mineralized matter about six feet in width lying entirely in the quartzite. This vein lies approximately parallel to the quartzite-granodiorite contact. It appears to represent a fracture in the country rock which has been the avenue for mineral bearing solutions from below to precipitate their salts. It was impossible to determine whether this fracture extended down into the granodiorite or not. The vein material consists of impregnations, in the country rock along the zone of fracturing, of micaceous hematite which contains a small amount of scattered grains of chalcopyrite and bornite. Along with these, crystals of garnet, hornblende, and orthoclase have been developed. A large amount of pyrite also occurs in this vein. Further up the hill towards the summit of the ridge several other small tunnels have been driven on the same vein and on a parallel vein which are heavily impregnated with pyrite and a smaller amount of chalcopyrite. The latter mineral occurs sparingly desseminated throughout the entire contact zone for a distance of 1,000 feet from the granodiorite contact.

CALUMET MINE.

This property is located about six miles east of Index on the north side of Bitter creek and high up in the Gunn peak mountain mass where one of the tunnels is located at an elevation of 4,200 feet. This property is reached by the Sunset tram which extends up the north fork of the Skykomish river past the mouth of Bitter creek; from there, by a well constructed trail up the latter creek for a distance of one mile and a quarter, the trail for the last quarter mile being a switchback with a very steep grade. The main cabin is located at an elevation of 3,600 feet and the main tunnel about 500 feet higher. This property consists of four claims, which were located in 1897 by John A. Lewis, who sold it to John Rood. He built a tram from the mine to the lower camp on Bitter creek and later sold the property to W. S. Dewey, who is the present owner.

The development work consists of two tunnels and several open cuts. The lower tunnel starts at the center of the Manson claim at an elevation of 4,000 feet and has been driven on the vein into the hill along the direction north 75° east, for a distance of 500 feet. About 200 feet higher a second tunnel has been driven on the vein for a distance of 100 feet. These tunnels are difficult of access and guide ropes are used in reaching them from the main cabin. Formerly a bucket and gravity cable carried the ore from the mine to the lower camp on Bitter creek.

The country rock is entirely granodiorite and the ore bodies lie in fissure veins having a direction of north 75° east and a vertical pitch. In the upper tunnel the ore body is eight feet wide from wall to wall and the country rock on either side is more or less impregnated with chalcopyrite. The ore consists mainly of chalcopyrite with some pyrite and a very small amount of sphalerite imbedded in a gangue of quartz, crushed and altered granite, cemented with secondary silica. In the lower tunnel the downward extension of the same vein occurs, but is much narrower and in places appears to pinch out altogether, leaving the two granite walls in contact. This ore body is apparently the lower portion of a lens or ore shute lying in the fissure vein. No records of any ore having been shipped from this mine are available.

FLORENCE-RAE MINE.

This mine is situated on the south side of the north fork of the Skykomish river, on the ridge between Trout and Bitter creeks, in section 3, Tp. 27 N., R. 10 E., and is reached by trail four miles distant from Index. There are ten claims near the river which were located by F. G. Curtis, in 1898, and six others lying two in width up near the head of Bitter creek, which were located by him in 1910. These two groups, together with the Aribel and Pearl claims, which are situated on Curry creek on the north side of the Skykomish river, in section 3, Tp. 27 N., R. 10 E., belong to the Florence-Rae Lumber, Land and Development Company.

The development work on Bitter creek consists of trails, open cuts, and 150 feet of tunnel which constitutes the main mine working and is known as the Florence-Rae tunnel. It lies at an elevation of 1,780 feet and entirely in granodiorite. The ore is mainly micaceous hematite containing scattered grains of chalcopyrite, bornite and pyrite in a gangue composed of crushed and altered granodiorite. The general direction of the tunnel is north 45° east. The ore varies in width and appears somewhat irregular in distribution. It is presumed to represent the iron which has been left behind as a result of the downward leachment of the copper sulphides. Assays taken here vary considerably, ranging from two to fifty per cent. in iron and two ounces per ton of silver, with only a trace of gold.

THE BITTER CREEK MINE.

This property is located on Bitter creek in section 11, Tp. 27 N., R. 10 E., and consists of six claims known as the Wonder No. 1 Lode, Wonder No. 2 Lode, Standard Lode, Standard No. 1 Lode, Standard No. 2 Lode and the Maud. These were located in January, 1901, and amended locations were made in January, 1903, and surveys for patent in August, 1903. They were incorporated in the same year by B. U. Young and Nicholas Rudebeck as the Bitter Creek Mining & Milling Co. The development work consists of trails, cabins, tunnels and open cuts. The mine is located about four and one-half miles from Index and is reached from that place by the Sunset surface tram, extending up the north fork of the Skykomish as far as the mouth of Bitter creek and thence up that creek by horse trail. There are two tunnels on the Standard Lode, consisting of an upper one 600 feet long and a second one 100 feet below and about 200 feet in length, at an elevation of 3,300 feet. These have been driven in on the vein, which has a general trend of about north 66° east. The country rock is entirely granodiorite and the vein material occurs in a fissure zone filled with crushed and altered granodiorite about two feet in width and carrying bornite with some chalcopyrite and pyrite and a little micaceous hematite. Many samples of high grade ore occur, but the average ore of the vein is low grade.

INDEX BORNITE MINE.

This property is situated on Lewis creek, about two miles distant from Index, from which point it is reached by tram road and trail. During the last year the Index-Galena Lumber Company has constructed a broad-gauge track, connecting with the main line of the Great Northern Railway at Index, to a point about one mile from the mine. This road is used principally for hauling out logs, but if extended could be used for transporting ore. There are two claims, the Barry and Hillside, which were located on May 20th, 1898, by Alec Watt, Chas. E. Cummings and York Barington. On June 2nd, 1899, these were incorporated as the Index Bornite Copper Mining Company.

The development work consists of 700 feet of tunnel, together with trails and cabins. On the center of the Barry claim there is a 70-foot shaft on the vein. On the creek a tunnel has been opened on the vein for 55 feet. A longer tunnel has also been opened which consists of a cross-cut to the vein and drifts to the right and left.

The country rock is granodiorite and the vein, which has a general direction of N. 65° E. with a pitch of 70° to the southeast, varies in width from four inches to four feet. In the shaft, it is four feet wide. In the main tunnel, where the vein is four inches wide, it is filled with pure bornite, where wider it is commonly banded with quartz and calcite and crushed granodiorite. The wall rocks are impregnated with small grains of bornite and occasionally chalcocite. Chalcopyrite occurs, but in small amounts. The walls are well defined and the ore bodies in depth will conform to the general rule applying to all in the camp—namely, lenses in the plane of the vein.

INDEX PEACOCK MINE.

There are four claims in the group which is situated on Canyon creek above the Gunn peak mine. The claims were located in 1897 and are owned by A. M. Watt, of Seattle. A tunnel has been driven on the vein for a distance of 100 feet. The vein strikes N. 65° E., is about four feet wide and composed of soft decomposed granodiorite, containing some disseminated bornite and chalcopyrite. The surrounding rock is granodiorite, but a narrow dike of fine grained diorite porphyry standing almost vertical, extends along nearly parallel to it.

GUNN PEAK MINE.

There are five claims belonging to this property which were located in July, 1897, by A. M. Watt and Chas. E. Cummings. These were incorporated on August 10, 1897, as the Gunn

Peak Copper Mining Co. The mine is situated on Canyon creek, about one-half mile east of the Index Bornite mine and is reached from Index by trail up the north fork of the Skykomish river.

There are two tunnels, one of which is 455 feet long and the other 10 feet, on Canyon creek, at an elevation of 2,500 feet. The country rock is granodiorite and the vein, which has a strike of N. 65° E. with a vertical pitch, is three feet wide and is composed of crushed granite with a very little chalcopyrite and bornite scattered through it.

HELENA MINE.

This property is located one-half mile to the northeast of Index in the northwestern part of section 16, Tp. 27 N., R. 10 E., on the slope of the high mountain ridge forming the north wall of the Skykomish valley. It consists of two claims, the Tillicum and Tillicum Hill, located on the same ledge and having a general trend of north 45° east. These claims were located in May, 1899, by Mr. Wm. Cornwall, of Index. Development in the form of assessment work has been done continuously up to the present time. It consists of three tunnels driven into the hill on the vein which aggregate about 225 feet. The country rock is entirely composed of granodiorite and the vein, which averages about four feet in width, has a very steep dip to the south. The vein material consists of chalcopyrite, bornite and pyrite, with a gangue of quartz, calcite, and altered granodiorite. Much of the ore is banded, showing successive layers averaging about an inch in thickness, of chalcopyrite and pyrite alternating with narrow bands of altered and recemented granodiorite.

NORTH STAR MINE.

This property is situated about three miles northeast of Index on the north side of the north fork of the Skykomish river. It is reached by the Index-Galena wagon road for two and three-quarters miles and then by a trail extending northward for about one mile up North Star creek. There are fourteen claims and these are owned by the North Star Mining Company. The Metropolitan, Metropolitan Extension No. 1, and the Pacific Star were located by C. E. Larson on April 7th, 1900. Three more were located by him June 7th of the same year and the remainder by S. E. Illig in January, 1903. The development consists of about 1,100 feet of tunnel. The main tunnel opens at an elevation of 2,570 feet and extends into the hill as a cross-cut for a distance of 630 feet, where it intersects the vein. This has a general trend of N. 24° E. and a pitch of 78° to the northwest. A drift has been driven to the right 150 feet and one to the left 180 feet. A second smaller tunnel has been driven in higher up the mountain.

The country rock is entirely granodiorite and the vein is of the fissure type, filled with crushed and altered wall rock and re-cemented by silica, and containing bands of bornite and chalcopyrite, varying in width from two inches to three feet. In places, as in the right-hand drift, the vein is much wider and does not contain copper ore throughout its entire width. Chalcopyrite and pyrite occur, but in subordinate amount.

INDEX INDEPENDENT MINE.

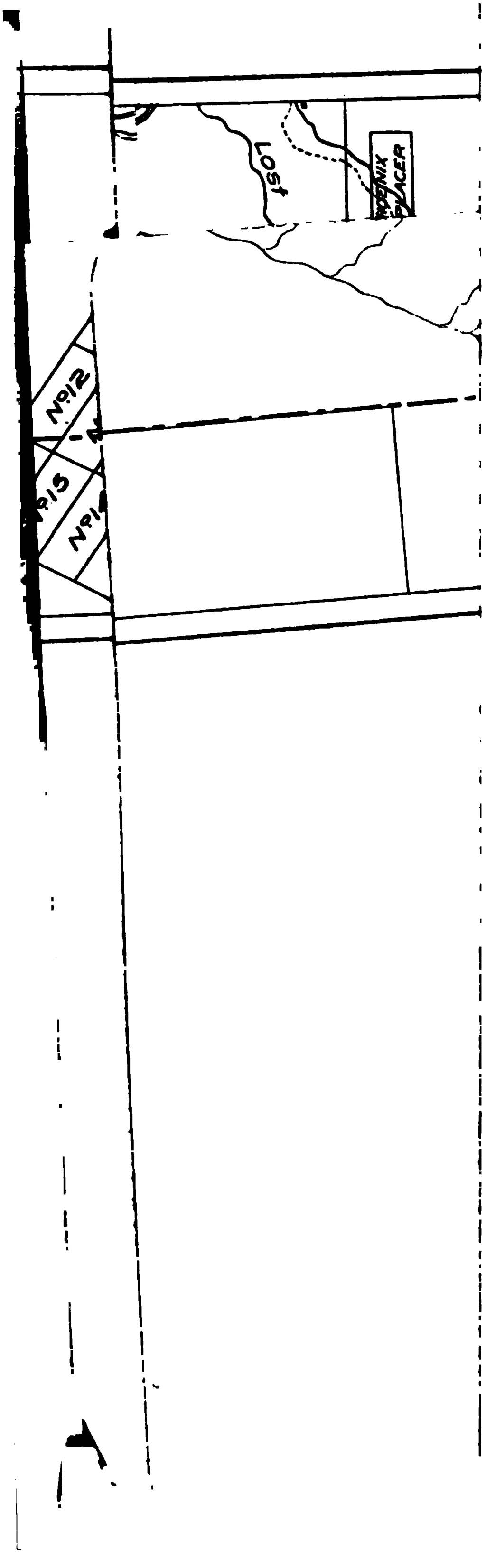
This property is located about two miles south of the town of Index in the southern part of section 30, and northern part of section 31, Tp. 27 N., R. 10 E. It lies on the south side of the Skykomish river and is reached by a suspension bridge and trail, which connect with the O. and B. Lumber Company's mill on the Great Northern Railway, one and one-half miles from Index. This property consists of five claims, viz., the Mystery, Pride of Index, Sixteen to One, Crown Jewel and the Copper Queen. These were located in 1898, amended in 1906 and a patent obtained. They are owned at present by Mr. Lot Wilbur of Snohomish, Washington.

The development work on this property is confined almost entirely to the Sixteen to One claim. This consists of three tunnels driven in southwesterly on the same vein at different elevations. The lowest, at an elevation of 1,200 feet, is 470 feet in length. The mouth of this tunnel lies at the base of a vertical granite cliff. The second tunnel, which is 125 feet higher, is reached by a switchback trail and has been driven in on the vein a distance of 170 feet. The third tunnel is 100 feet higher than the second one and has been driven in 261 feet. Several open cuts have been made on the outcroppings of the vein on the other claims, but no other underground development work has been done. A few hundred feet north of the mine are a blacksmith shop and cabin.

The country rock in this property is entirely granodiorite, which to the south and west is overlaid by metamorphic and volcanic rocks. The ores occur in distinct fissure veins, having a general strike of north 70° east, and pitching nearly vertical or steeply to the south. In the vincinity of the vein the granite is often cut by dikes of granodiorite aplite, running diagonally to the general trend of the vein. The ores are copper and consist mainly of bornite, chalcocite and chalcopyrite, with some pyrite. The fissure vein consists of small lens shaped ore bodies lying in the plane of the fissure with intervening barren areas.

BUCKEYE MINE.

This property, consisting of sixteen full sized claims and two mill sites, is located about six miles to the southeast of the town of Index on the south side of the Skykomish river and Great Northern Railway, in section 33, Tp. 7 N., R. 10 E., and is owned by the Buckeye Copper Company. The claims are all full size, extend in a direction south 29° 26′ east and are known as the Buckeye Nos. 1 to 16. The two mill sites are known as the Buckeye and Mountain View. These claims lie on the north flanks of the mountains forming the divide between the Skykomish and the Tolt rivers and extend over the Snohomish county line into King county. This property is reached by a trail built from a point on the Great Northern Railway about one mile west of Halford at Eagle Falls on the Skykomish. At this point the river is crossed by a footbridge


Lost
HOENIX PLACER
No. 12
No. 13
No. 1

and the trail is about one and one-half miles in length to the mine.

These claims were located in 1898 and again re-located in 1906 and surveyed for patent. The development work on this property consists of trails, bridges, bunkhouses, cookhouses, barns, numerous open cuts and three tunnels. The most extensive workings are confined to the Buckeye claims Nos. 5 and 9. Altogether approximately 1,500 feet of tunnel have been driven. The largest tunnel begins on the center lode of No. 5 claim and has been driven in southwesterly for a distance of 650 feet on the vein.

At the face of the main drift a cross-cut has been run to the left along a direction north 40° west for a distance of seventy feet where a second parallel vein is encountered. From here a drift is driven on this vein for a distance of about 500 feet in a direction south 40° west, then the main cross-cut was continued on from the point of intersection with the second vein, in a direction north 30° west, for about 150 feet. The rock is hard and costs about twenty-five dollars per foot to drive. An air compressor has been installed near the entrance to the main tunnel, but it is now out of commission. Since 1907 very little development work has been done.

All of the veins within this property are confined to the granodiorite which, to the south and west, is overlaid by a series of quartzites, slates, and volcanic rocks. The ores occur in distinct fissure veins and extend in a general direction north 40° east, pitching nearly vertical or very steeply to the southeast. The vein varies in width from a mere seam to six feet. The fissures and walls are well defined, and the ore bodies are distributed along them in irregular, lens-shaped bodies, leaving intervening areas of barren rock represented by a very narrow stringer of quartz and calcite. The ores are predominately copper and are represented by chalcopyrite, with a small amount of cuprite, bornite, and chalcocite. The large ore bodies are composed of a gangue material made up of crushed country rock which has been partly converted into kaolin and partially cemented by silica with calcite, and contains scattered through it, irregular bunches, stringers and grains of the above mentioned copper minerals. The ore does not appear to occur in large bodies and is typically low grade. The general samples collected gave assays ranging from one to two dollars in gold with a trace of silver.

No statistics are available on the amount of ore taken out of this property. Several tons are said to have been packed out on horseback and shipped to the Tacoma smelter, but no data are available concerning the returns on this shipment. The larger part of the ore taken out lies on the dump at the mine. The estimated cost of improvements, including the underground development of the mine, is approximately $27,000.

COPPER BELL MINE.

This property is located about five miles west of Index and is reached from Reiter, a small station on the Great Northern Railway, by a tram road less than one mile in length. The property consists of eighteen claims, which are owned by the Bunker Hill Mining & Smelting Co. The Copper Bell and South Copper Bell claims were located on January 12th, 1897, by C. H. Gray and L. W. Gray. On May 5, 1897, the Copper Bell Mining Company was organized, taking over the Copper Bell, South Copper Bell, Homestead, Jumbo, Buncombe, Warcry, Joker, Echo and Shamrock claims.

Development work consists of approximately 2,700 feet of tunnel. The main tunnel has been driven on the South Copper Bell claim through the Copper Bell and into the Jumbo claims on the main vein, a distance of about 2,400 feet. Branching off from this at numerous places are shorter tunnels. About 600 feet from the mouth, a cross-cut has been driven both to the right and to the left. To the left the main ore body was encountered and a slope sunk on the vein and an upraise made to the tunnel above, through which the larger part of the ore from this mine has been taken out. Further to the north and higher up on the Jumbo claim, two shorter tunnels have been driven into the hill on what is probably the same vein, but a different ore lens, lying in the northeasterly extension of the same vein. The ore from these tunnels is transferred down hill by a gravity tram. A power plant has been installed on May creek and the water brought to it by flume from some distance up the creek. The power is transmitted from here to the concentrating plant and to the mine and buildings. Near the entrance to the main tunnel a large concentrating plant has been built, which has been described in the previous chapter under the heading "Treatment of Ores." In addition to this, a smelter has also been constructed at the lower camp on the Joker claim.

The country rock on this property is composed of granodiorite together with a series of metamorphic schists and quartzites. The contact between these two formations extends in a general northwesterly direction, with the granodiorite on the north and east, and the metamorphic series on the south and west, and crosses the main tunnel near the junction of the South Copper Bell and Copper Bell claims. The plane of contact is nearly vertical and, in a zone of quartzite, extending back 300 feet from the contact, are small apophyses and disconnected, irregular masses of the granodiorite scattered through it. The metamorphic rock within the tunnel is a hard, dark gray, fine to medium grained quartzite, which is locally called by the miners "diorite." The minerals comprising the ore consist mainly of chalcopyrite with occasional scattered bunches of bornite in a gangue composed of quartz and altered, crushed, re-cemented granodiorite. Near the surface much of the copper has been leached downward, leaving the iron sulphide behind in an altered form as micaceous hematite. The trend of the vein is approximately north 32° east, with a nearly vertical dip. The main ore body is a lens or ore chute, lying in the plane of the vein and has a maximum width of thirty feet, but narrows down both to the northeast and southwest as well as above and below. Much of the gangue in this lens is an extremely altered granodiorite, partially re-cemented by silica and impregnated with chalcopyrite, pyrite and bornite. On either side of the walls, which in many cases are nothing more or less than gradations from the ore body proper into the country rock, are small scattered granules of chalcopyrite and bornite together with iron sulphide.

The ore deposits occurring in the upper workings on the Jumbo claim are much narrower, but contain the same minerals. They appear to form a part of a smaller ore lens lying in the Copper Bell vein proper. In both cases these lenses must be considered as zones in the main fissure vein in which a larger area has been ground up as the result of fracturing, and in which the ore solutions have had a better chance to circulate.

RED CROSS MINE.

This property, owned by the Red Cross Mining Company, lies in the western part of the district, two miles north of Reiter, as above and below. Much of the gangue in this lens is an at an elevation of about 3,000 feet. It is reached by trail, connecting with the tramway and horse trail of the Bunker Hill mine. There are ten claims in this group upon which several open cuts have been made. The short tunnels have been driven but no extensive work undertaken. The country rock is granodiorite and the ore occurs in fissure veins having a general trend of N. 40° E. The ore minerals are chalcopyrite, bornite and pyrite in a quartz gangue.

THE INDEX GRANITE QUARRY.

This quarry is located one-half mile west of Index, on the Great Northern Railroad and is owned by J. A. Soderberg, of Seattle. The rock, which is a part of the Index granodiorite, outcrops on a vertical cliff on the south side of the long ridge between the Skykomish river and Deer creek. It is pretty constant in petrographical character and is almost entirely free from ovoid basic secretions and joints. It has been quarried for several years and the stone has been used for paving blocks, building stone, and street curbing.

THE HALFORD GRANITE QUARRY.

About one-fifth of a mile west of Halford on the Great Northern Railway, is a steep bluff of granodiorite, jutting out at the railway track. A quarry has been opened up by the railroad company and the material is used for riprap along their roadbed. The rock is considerably weathered and contains many joints and is not adapted for building purposes.

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